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THE TECHNOGRAPH

No. 21 UNIVERSITY OF ILLINOIS 1906-1907

COST OF SHOP DRAWINGS FOR STRUCTURAL IRON AND STEEL.

By Ralph H. Gage, '03, Civil Engineering.

The following data were gathered by the writer while in charge of the Drafting Department of A. Bolter's Sons' Structural Steel and Iron Works, of Chicago, Ill., during the years 1904, 1905, and 1906.

The Works are divided into three different departments, the Structural Shop, the Architectural Shop, and the Foundry. The Structural Shop has a capacity of 800 tons per month. The Drafting Department employes on an average seven or eight engineers. All the work is standardized with regard to details to as great an extent as possible, in order to decrease the work in the Drafting Room, yet not to such an extent that it would be difficult for the shop men to read the drawings. For example, all beam, steel and cast-iron column connections, with the exception of special cases, are not drawn and dimensioned completely, but merely indicated. The shop and drafting room have been provided with a set of the firm's standards, which have all these connections drawn out completely with dimensions and which give lists of the material.

The data here presented were taken from a great variety of work, such as public and private school buildings, churches, breweries, malt houses and elevators, grain bins, warehouses, libraries, hospitals, apartment buildings, factories and manufacturing plants, train sheds, mill buildings, office buildings, electric lighting plants and pumping stations.

Table I shows the character of the buildings and also the average cost of preparing the drawings. The cost of drafting material and blue prints is not included. Where the material for the work is to be ordered from the mill and not taken from stock, the cutting bills or mill orders are taken as being part of the details. Table II shows some of the particulars of the buildings from which the data in Table I were derived and the following notes give additional information about some of the work.

TABLE I.

COST OF SHOP DRAWINGS.

TYPE	CHARACTER OF BUILDING	AVERAGE COST PER TON
A	Entire skeleton construction, i. e., loads all carried to the foundation by means of steel columns	$1.45
B	Interior portion supported on steel columns; exterior walls carry floor loads and their own weight	1.22
C	Interior portion carried on cast iron columns; exterior walls support floor loads as well as their own weight	.70
D	No columns and floor beams resting on masonry walls throughout	.85
E	Structure consisting mostly of roof trusses resting on columns	2.47
F	Structure consisting mostly of roof trusses resting on mosonry walls	1.25
G	Mill buildings	2.56
H	Flat one-story shop or manufacturing buildings	.74
I	Tipples, mining structures or other complicated structures	4.88
J	Malt or grain bins and hoppers	2.47
K	Remodeling and additions where measurements are necessary before details can be made	1.87

Item 2. The Faxton, Horton & Gallagher building was a fire escape of unusual size, composed almost entirely of angles, and designed for a seven-story building. It was a very light structure having railings and balusters of 1″ x 1″ x ¼″ angles. This accounts for the high cost per ton for the shop drawings. The details were made of the fire escape assembled and not separate details of each piece.

Item 3. The cost of the Miller Brewing Company Stock House was unusually low, only thirteen cents per ton. The building con-

TABLE II.

Details of Data Summarized in Table I.

Item	Name of Structure	Location	Type	Weight Tons	Cost of Details	Cost per Ton	Remarks
1	Evansville Brewing Co.	Evansville, Ind.	C	130.0	$107.40	$ .83	Complete Brewery
2	F. H. & G. Building...	Kansas City, Mo.....	I	17.0	85.80	5.05	Fire Escape
3	Miller Brewing Co....	Milwaukee, Wis.	C	295.0	38.20	.13	Stock House
4	Bullen Malt House....	Chicago, Ill.	F	26.5	23.90	.90	Rebuilt after fire
5	Lincoln Park Aviary..	" "	E	33.0	17.80	.54	Bird and Animal House
6	Metropolitan Elev. Ry.	" "	A	113.0	131.60	1.17	Terminal Station
7	Dahl Building	" "	B	35.0	44.75	1.28	Apartment Building
8	Fred W. Wolf Building	" "	A	280.0	78.50	.28	Machine Shop
9	Wahl-Henius Institute.	" "	C	29.0	35.50	1.22	Brewer's School
10	Crane Co. Building....	" "	C	43.5	19.50	.45	Stable
11	Oriental Consistory ..	" "	K	120.0	58.60	.49	Remodeled
12	St. Nicholas Church..	Evanston, Ill.	D	29.0	24.00	.83	Catholic Church
13	National S & E. Co....	Chicago, Ill.	D	181.0	93.00	.51	Warehouse
14	Crane Co. Building...	" "	C	108.0	61.00	.57	Office Building
15	Peru Brewing Co.....	Peru, Ill.	C	55.0	19.00	.35	Stock House Addition
16	Walter Brewing Co...	Appleton, Wis.	C	45.0	23.00	.51	Brew House
17	Schott Building	Chicago, Ill.	B	22.0	25.00	1.14	Apartment Building
18	White City Tower....	" "	A	260.0	723.00	2.78	Ornamental Tower
19	Schwenk-Borth Brew'y	Yankston, S. D.....	C	25.0	15.00	.60	Brew House
20	House of Good Shep'd	Chicago, Ill.	B	187.0	108.50	.58	Home for Girls
21	Edw. Ahlswede Bldg.	" "	K	26.0	43.00	1.66	Remodeled
22	Newaygo Portl'd C'm't	Newaygo, Mich.	I	7.5	32.00	4.26	Tipple
23	Sears-Roebuck & Co...	Chicago, Ill.	F	427.5	319.00	.75	Train Shed
24	Nelson-Morris Co.....	Kansas City, Mo.....	D	50.0	58.60	1.17	Boiler House
25	American Malting Co..	Kensington, Ill.	B&C	660.0	584.00	.89	Malt House
26	Walter Bros. Brew. Co.	Menasha, Wis.	C	25.5	15.30	.60	Brew House
27	R. Wosslick Building.	Chicago, Ill.	B	22.0	50.00	2.28	Apartment Building
28	Barwig Bros. Building	" "	C	30.0	23.80	.80	Store Building

Item	Name of Structure	Location	Type	Weight Tons	Cost of Details	Cost per Ton	Remarks
29	St. Gregory Church...	" "	C	65.0	17.80	.27	Catholic Church
30	Welch Pres. Church...	" "	E	22.0	77.00	3.50	Addition
31	Missoula Mercantile Co	Missoula, Mont.	D	23.0	27.50	1.20	Stock House
32	Chicago Dock & Canal	Chicago, Ill.	C	179.0	82.60	.46	Mill Construction
33	Knoop Building	" "	C	31.0	23.00	.74	Store & Flat Building
34	Chicago Athletic Club	" "	A	88.0	198.00	2.25	Remodeled & Addition
35	Diversy Blvd Church..	" "	F	34.5	94.40	2.74	M. E. Church
36	Lawrence Ave. Station	" "	E	115.0	166.50	1.45	Pumping Station
37	Schoenhofen Brew. Co	" "	C	40.0	10.00	.25	Stable
38	People's Gas L. & C Co	Chicago, Ill.	C	21.5	26.00	1.21	Gas House
39	Convey Placer Min. Co	Ruby, Mont.	I	47.0	378.00	8.45	Steel Flume & Bridge
40	Western Foundry Co..	Chicago, Ill.	F	81.0	34.00	.42	Foundry
41	LasVegas Elec. Ry. Co.	Las Vegas, N. M.....	C	31.5	24.30	.77	Car Barn & Power H.
42	Western Electric Co...	Chicago, Ill.	A	93.0	40.00	.43	Factory Building
43	French Lick Hotel...	French Lick, Ind.....	D	52.5	30.00	.57	Sanitarium
44	Minneapolis Brw. Co..	Minneapolis, Minn. ...	C	534.0	303.00	.57	Bottling House
45	Jos. M. Ward Bldg....	Battle Creek, Mich. ..	B&C	50.0	324.00	6.50	Office Building
46	C. A. Wightman Bldg.	Evanston, Ill.	B	64.0	121.50	1.90	Store and Office Bldg.
47	VanVlissingen School.	Chicago, Ill.	C	196.0	185.00	.95	Public School
48	Stephen Hayt School.	" "	C	465.0	429.00	.93	Public School
49	Dallas Brewery	Dallas, Tex.	C	26.0	17.50	.67	Stock House
50	Gambrinus Brew. Co..	Columbus, Ohio.	C	300.0	233.00	.78	Complete Brewery
51	Malt Bins for above..	" ".....	J	19.0	68.40	3.60	Steel Bins & Hoppers
52	Western Electric Co...	Hawthorne, Ill.	H	45.0	25.00	.56	Carpenter Shop
53	L. Z. Leiter Estate....	Chicago, Ill.	A	140.0	252.00	1.80	Store and Office Bldg.
54	Col. DuPont Building.	" "	A	119.0	32.00	.27	Warehouse
55	South Bend Gas Co...	South Bend, Ind.	C	28.0	24.30	.87	Gas House
56	Carson, Pirie,Scott&Co	Chicago, Ill.	K	28.0	121.50	4.35	Bridge
57	King Joy Lo Co.....	" "	K	61.0	64.50	1.05	Chinese Restaurant

58	National Machine Wks	" "	H	51.0	68.00	1.33	Machine Shop
59	Western Electric Co..	Hawthorne, Ill.....	H	388.5	171.00	.44	Shop and Kiln Bldg
60	The Fey Building....	Chicago, Ill.	B	13.5	18.00	1.33	Apartment Building
61	The Beach View Bldg.	" "	B	16.0	24.00	1.50	Apartment Building
62	Evanston Library	Evanston, Ill.	B&E	129.0	570.00	4.47	Public Library
63	Feeble M'd & Epil Schl	Marshall, Mo.	D	70.0	68.00	.97	School and Asylum
64	Knickerbocker Ice Co.	Chicago, Ill.	F	65.5	81.00	1.24	Stable
65	Oak Park Hospital...	Oak Park, Ill.	C	250.0	480.00	1.92	Catholic Hospital
66	Otis Elevator Co.....	Chicago, Ill.	G	76.0	82.60	1.09	Foundry
67	C. & N. W. Ry Shops	" "	F	64.0	44.00	.69	Locomotive Shops
68	Crescent Brewing Co..	Nampa, Idaho	C	101.0	84.50	.84	Complete Brewery
69	Ravenswood Hospital.	Chicago, Ill.	D	20.0	23.80	1.19	Private Hospital
70	Ullrich Bros. Bldg....	Evanston, Ill	C	80.0	45.50	.57	Store and Office Bldg.
71	W. A. Wieboldt Bldg..	Chicago, Ill.	C	71.0	91.50	1.29	Store and Office Bldg.
72	Garrett Biblical Inst..	Evanston, Ill	B	39.0	231.00	5.93	Library Annex
73	National S. & E. Co...	Chicago, Ill.	D	76.5	27.00	.35	Warehouse
74	North Ave. State Bank	" "	B&C	30.0	58.75	1.96	Store and Office Bldg.
75	Chicago Telephone Co.	" "	B	73.0	54.70	.75	Branch Exchange
76	St. Stanislaus Hall....	" "	F&B	153.5	250.30	1.63	Hall and School Bldg.
77	Gould Elevator Co.....	Minneapolis, Minn....	J	111.0	93.50	.84	Grain Elevator
78	Birk Bros. Brewing Co	Chicago, Ill.	C	38.5	35.00	.91	Bottling House
79	Fred Miller Brew. Co.	Milwaukee, Wis.....	C	32.0	52.00	.16	Stock House
80	Alling Construction Co	Chicago, Ill.	I	10.0	58.00	5.80	Tank Support
81	Western Foundry Co..	" "	F	102.0	162.50	1.59	Foundry
82	H. E. Barrett Building	" "	B	23.0	25.50	1.11	Apartment Building
83	Gambrinus Brewing Co	Columbus, Ohio.	C	83.0	55.50	.67	Bottling House
84	Miller Brewing Co....	Milwaukee, Wis.....	C	720.0	100.00	.14	Bottling House
85	Knickerbocker Ice Co.	Chicago, Ill.	E	41.5	46.60	.96	Refrigeration Plant
86	Schoenhofen Brew. Co	" "	C	415.0	264.50	.64	Complete Brewery

sisted of very heavy beams, 15″ 60-lb. I's and 20″ 80-lb. I's. Separate details were made of each piece, but as there were many duplicates, the cost was low.

Item 8. The Fred W. Wolf Company Building, while composed of riveted steel columns, beams and trusses, was square and the various pieces had many duplicates.

Item 18. The White City Tower consisted of sixteen riveted steel columns rising to a height of about 250 feet above the ground, with an elaborate system of diagonal angles for wind bracing. There were no floor systems throughout the entire structure. It might be interesting to state here that during the erection of this tower not a single piece had to be cut or a hole drilled, and only two holes had to be reamed in the field.

Item 22. The Newaygo Portland Cement Company's tipple was similar to the ordinary coal tipples. The details were made of the structure assembled, and show all necessary views and sections.

Item 23. The Sears, Roebuck & Company train shed was composed of a long row of trusses resting on masonry walls and anchored to same, with a hip roof at one end and vertical framing for glass at the other end.

Item 30. The Welch Presbyterian Church consisted of a very complicated hip and valley roof whose trusses rested on steel columns built in the walls.

Item 35. The Diversey Boulevard M. E. Church was composed of a hip roof, but the trusses rested on and were anchored to the masonry walls.

Item 36. The Lawrence Avenue Pumping Station consisted of trusses supporting a hip roof resting on masonry walls, a crane runway of 24″ 80-lb. I's resting on Z-bar columns, and floor beams resting on concrete walls.

Item 39. The Conrey Placer Mining Company's structure was very complicated, and consisted of a long steel flume supported by a bridge-like truss, and other placer mining devices, such as sluice gates, grizzleys. The structure was of comparatively light weight, and there being no duplicate parts, the cost of details was high.

Item 44. The Minneapolis Brewing Company Bottling House is a fire-proof structure with two floors and a roof. The floor beams rest on the exterior masonry walls and frame into cast iron columns

on the interior. The roof is supported by small trusses resting on cast-iron columns and the exterior walls.

Item 45. The Jos. M. Ward building was a store and office building built partly over a small river. The foundations for the columns were laid in the river bed, and those columns which came in contact with the water were made of cast iron and braced in all directions with 1¼" sway rods, while the remaining columns were of steel. Riveted plate girders under the first floor spanned the river which flowed almost directly under the building.

Item 54. The DuPont Building was a warehouse of the ordinary skeleton construction and very plain and square. All the columns were practically alike, and the beams were similar for all floors, hence the low cost for the details.

Item 56. The Carson, Pirie, Scott & Co. bridge consisted of a double bridge or passageway across an alley connecting their two buildings. As the walls of each building were only curtain walls, the girders rested on columns next to the walls running from the ground up. All measurements such as floor heights and distances between walls had to be taken at the building, and the expense incurred for taking these measures is included in the cost of details.

Item 62. The Evanston Public Library, while a low two-story building with all floor beams and trusses resting on masonry walls, except for a few interior cast iron columns, had a very crooked hip and valley roof, also suspended ceilings and skylights. The ceiling and skylight were made of small tees and channels, and hung from the roof trusses.

Item 64. The Knickerbocker Ice Company stable was a three-story building constructed so that the second and third floors were suspended from the roof, thereby leaving no columns to obstruct the main floor. The roof trusses spanned about sixty feet and were correspondingly heavy.

Item 65. The Oak Park Hospital was a strictly fire-proof structure composed of cast iron columns and steel floor beams. The roof was a hip and valley roof made up of channels, beams and tee iron, which in turn were covered with tile.

Item 66. The Otis Elevator Company Foundry building was constructed on the common mill building plan with riveted steel col-

umns, trusses, crane runway, purlins, and bracing, which needs no further description.

Item 72. The Garrett Biblical Institute Annex, while a small building containing only 39 tons of structural steel, has a complicated hip roof with dormer windows. The entire roof was covered with 1½" x 1½" x ¼" angles, all fitting around the dormer roofs for Ludowici tile.

Item 76. The St. Stanislaus Hall building consisted mostly of large plate girders and high A-shaped trusses.

Item 77. The Gould Elevator is a large grain elevator with reinforced brick sides and steel hopper bottoms. The hoppers were made of 5-16" steel plates and were supported by heavy plate girders, which in turn rested on the exterior masonry wall and on interior steel columns. The plates for these hoppers, some of which were sixteen feet square when assembled, were all shipped loose and assembled at the building.

Item 78. The Alling Construction Company tank support was of the ordinary four post construction. The posts were made of beams and had a slight batter. The bracing was composed of angles.

Items 80 and 85. The Fred Miller Brewing Company stock house and bottling house were both constructed with very heavy floor systems and cast iron columns. The buildings were square and required few details, as most of the floor beams were alike.

Item 81. The Western Foundry Company building was mostly roof-truss work consisting of 120-foot trusses resting on masonry walls with a cast-iron column in the center. Suspended from these trusses was a beam trolley-track with a number of curves and switches which made the detailing more expensive than it would have been for ordinary roof truss work.

There is always a noticeable decrease in the cost of the details when the plans for the ironwork are made and designed by an engineer and separated from the general plans. On comparing the cost of picking out the structural steel and making the shop drawings from the architect's plans and the engineer's plans, it was found that the cost of the former is on an average of 35 per cent higher than the latter. Where the engineer's plans are made with no dimensions, with only the outline and sections given, it being necessary to refer to the general plans for the location and dimensions,

there is no saving of time, and the detailing runs as high as on the architect's plans.

Inaccurate plans, where the draftsman is continually finding errors, cause an increase in the cost, as it is necessary to wait and refer the matter to the architect; and in most cases he, in turn, has to check over his plans before he can settle the question, all of which causes considerable delay and takes time that might otherwise be spent in making the drawings.

The cost of structural steel details depends on so many things that it is hard to set any fixed rule for determining what this cost is. The type of the building is the first consideration; then the architect and engineer, their methods of drawing up their plans; and finally the detailing drafting force one is obliged to depend upon.

SPECIFIC HEAT OF SUPERHEATED STEAM.

By Henry B. Dirks, M. E., '04.

The first important determination of the specific heat of steam, was made by Regnault in 1862, when he obtained the well known value of 0.48 as the mean specific heat at atmospheric pressure between 128 and 221° C. The calculations of Mallard and LeChatelier, 1883, and Berthelot and Vieille, 1885, on the principle of the explosion tests followed and pointed to a strong increase of the specific heat with the temperature, however gave no conclusions as to the influence of pressure. With the increase in the use of superheated steam in both the steam engine and of late years the steam turbine, there came the desire for further knowledge regarding the specific heat at constant pressure, and the properties of steam dependent thereon, which fact was the cause of several later observations. Those of Langen, 1903, based on the same principle as the above by Mallard and LeChatelier and also the calorimetric determination at atmospheric pressure of Holborn and Henning, 1905, point to an increase of Cp. with the temperature at high temperatures.

The first experiments to determine the variation of the specific heat with the pressure were those of Grindley, 1900, who with a throttling calorimeter in which in throttling from pressures of 14 to 2 atmospheres he produced superheated steam at lower pressures, found the specific heat to be independent of the pressure. This, however, was contrary to most of the theories which had been previously advanced and made further experimental investigation desirable. This was done by H. Lorenz in 1905, who from calorimetric determinations deduced the important fact that Cp decreases with the temperature from saturation whereas at a given temperature it increases with an increase of pressure, a result which H. Callendar had obtained but shortly before, 1901.

The more recent work of Messrs. Knoblauch, Linde and Klebe at the laboratory for technical physics of the Technical High School

Editors Note.—A translated review of the results of experiments by Knablauch and Jakob, performed at the laboratory for technical physics at Munich.

at Munich, 1905, on the properties of superheated steam, from which they deduced a general equation between pressure, volume and temperature and therefrom derived an expression for the specific heat, seems to bear out in general the results of the experiments of Lorenz. The actual observed values of Lorenz and those calculated by Linde however, show considerable differences. It was because of this fact that the investigations at the laboratory of the Technical High School at Munich were continued for another year and a half. This work was carried on by Messrs. Knoblauch and Jakob and included experiments for the determination of Cp from the vicinity of Saturation to 350° C. for pressures of 2, 4, 6 and 8 atmospheres.

Apparatus: The apparatus used in these tests of Messrs. Knoblauch and Jakob is shown in Fig. 1. The steam was taken from a boiler and next passed through a separator to remove the moisture. The steam was then totally dried and brought to a temperature t_1 in the first vertical, electrical superheater, and in a second electrical superheater, (the actual test apparatus) further heated to a temperature t_2 by means of an accurately measured electrical input of W Kg. cal. per hr., minus the heat loss, V Kg. cal. per hr., due to radiation, convection, etc. Finally the steam was condensed in two consecutive condensors, and its weight G Kg. per hr. determined by weighing. From the above quantities the maen specific heat for the temperature range from t_1 to t_2 is

$$Cp = \frac{G\ (t_2 - t_1)}{W - V} \qquad (1)$$

For small values of $t_2 - t_1$, this means specific heat is very close to the actual specific heat at the temperature $\frac{t_1 + t_2}{2}$.

The purpose of the first superheater was simply to give to the steam the required temperature at which the test was to be made, and to insure its being in a uniform condition. For this purpose the first superheater was made of considerable length with electrical surface heaters in its upper end and a series of wire netting in its lower end. In this manner enough heat was added to the steam at the very beginning to give the necessary degree of superheat and was later thoroughly mixed in passing through the wire netting.

In this uniform condition the steam passed through the pipe R_1 to the second superheater, the actual test apparatus, shown in Fig. 2.

This second superheater is in reality an electrically heated oil bath, through which the steam is passed in a copper coil of over 16 feet in length and 0.71 inch internal diameter. The heater has a resistance of $17^1/_4$ Ohms and on the average carried a current of 8.3 Amp.

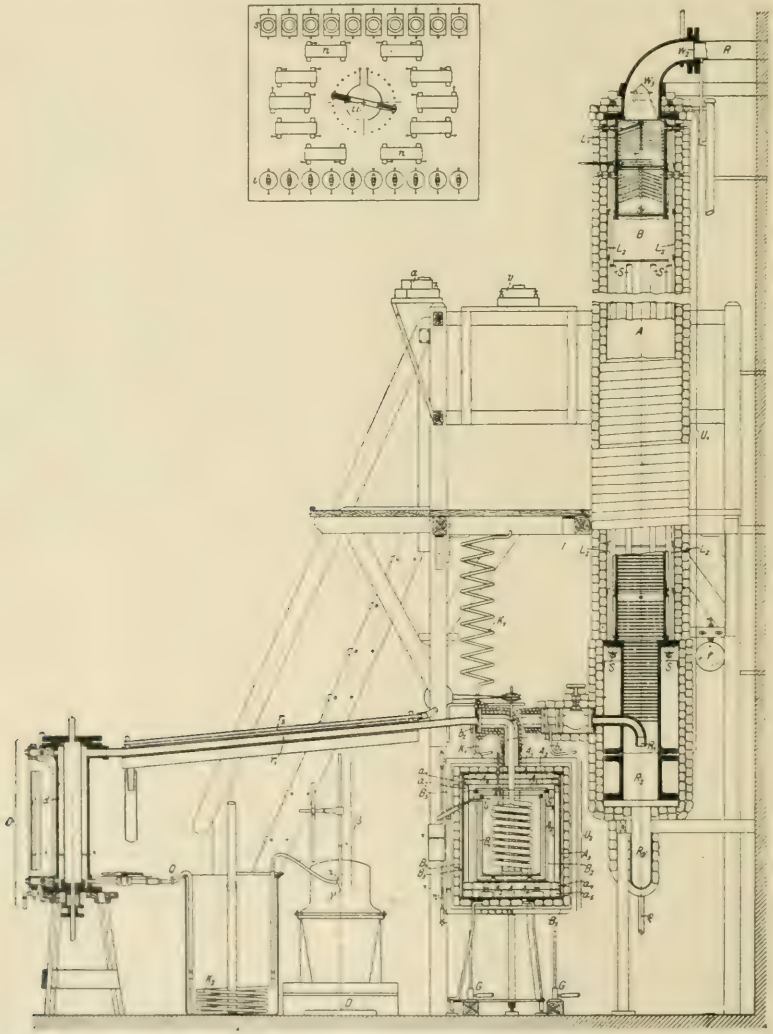


FIG. 1.—APPARATUS USED FOR FINDING Cp OF SUPERHEATED STEAM.

at 143 volts, a capacity of nearly 1.2 K. W. The oil bath was thoroughly insulated by means of asbestos and air spaces outside of which there was a steam jacket in which water was continually kept at the boiling point, thus tending to decrease radiation losses and make them constant. The incoming and outgoing steam temperatures were measured in the oil filled thermometers cups H_1 and H_2, these being axially placed in the steam pipes. The temperature

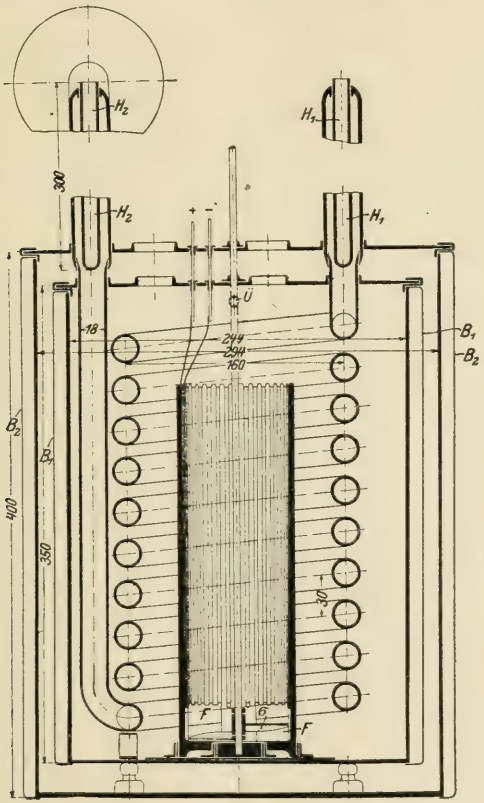


FIG. 2.—SUPERHEATER.

of the oil bath was taken by another thermometer placed between the steam coil and the electric heater. A propeller shaped stirrer at the bottom of the oil bath kept the bath at a uniform temperature. Openings in the steam pipe before and after entering the thermostat were connected to a pressure gage f, Fig. 1, by means of copper tubes.

From the second superheater the steam passed through 2 consecutive condensers, first through the slightly inclined pipe r_1, Fig. 1, which was cooled by water sprinkled from the pipe r_2 placed directly above it. The regulation obtained from this condenser was very simple and effective, necessitating only the regulation of the cooling water. From this condenser the mixture passed through the second condenser O on which was attached a glass gage and from which any small variation in the flow of condensed steam could be observed. The mixture then passed through the cooling coils K_2 to insure against vaporization when passing into the weighing buckets. The dischargeing water was finally weighed on the balance D.

The test proper divides itself into two sections, first the main test, in which the increase in temperature $(t_2 - t_1)$ of the steam G Kg. per hr. due to the addition of W, W E per hr. is determined and an auxiliary test in which the heat loss V, W E per hr. is determined.

The first part of the test required on the average about 40 min., a period of 5 hours, however, being necessary before starting the test, to insure a condition of thermal equilibrium within the apparatus. Although it was not always possible to retain this condition during the test, it was always carefully observed that the temperature of the oil bath was the same at the beginning and end of the test.

The auxiliary test was made immediately after the close of the main test to determine the heat losses due to radiation, convection, vaporization of the oil, etc., which necessarily varied for the different tests. As soon as possible after the close of the main test, the steam was shut off and the electrical heat so regulated as to keep the temperature of the oil unchanged and equal to that of the main test. The heat necessary for this purpose was just that which was lost during the main test.

Calculation: From the observed values of the quantities, W, V, G, t_1 and t_2, the specific heat may be calculated from the simple equation (1) page ... in place of which we may more accurately write the following:

$$\int_{t_1}^{t_2} C_p \, dt = \frac{W - V}{G} \qquad (2)$$

This formula, however, presupposes that the pressure in the steam spiral is constant. As in reality some throttling occurred, so

that p_2 was on the average 0.06 less than p_1, another small correction had to be inserted. According to Regnault's formula the heat necessary to generate 1 Kg. of superheated steam from the absolute pressure P Kg. per sq. cm. and the temperature t° C is

$$\lambda = 606.5 + 0.305\ t_s + C_p\ (t - t_s)$$

wherein t_s denotes the saturation temperature. In this case therefore we have for the entering steam,

$$\lambda_1 = 606.5 + 0.305\ t_{s_1} + \int_{t_{s_1}}^{t_{s_2}} Cp\ dt.$$

and for the exhaust steam,

$$\lambda_2 = 606.5 + 0.305\ t_{s_2} + \int_{t_{s_2}}^{t_{s_1}} Cp\ dt.$$

From this the difference between the heats required to generate may be calculated to

$$\lambda_2 - \lambda_1 = 0.305\ (t_{s_2} - t_{s_1}) + \int_{t_{s_2}}^{t_2} Cp\ dt - \int_{t_{s_1}}^{t_1} Cp\ dt.$$

or to $\lambda_2 - \lambda_1 = 0.305\,(t_{s_2} - t_{s_1}) + \int_{t_{s_2}}^{t_{s_1}} Cp\ dt + \int_{t_{s_1}}^{t_2} Cp\ dt + \int_{t_1}^{t_{s_1}} Cp\ dt$

or finally to

$$\lambda_2 - \lambda_1 = 0.305\ (t_{s_2} - t_{s_1}) + Cp\ (t_{s_1} - t_{s_2}) + \int_{t_1}^{t_2} Cp\ dt.$$

In the latter form the allowable supposition is made, that, in the small interval from t_{s_1} to t_{s_2} (0.59° C. on the average) corresponding to p_1 and p_2, Cp remains unchanged. In these tests the difference $(t_2 - t_1)$ was on the average 39° C. The mean specific heat for this small interval is but very little different from the actual specific heat at the temperature $\frac{t_1 + t_2}{2}$. Accordingly the formula for $(\lambda_2\ {}_2\ \lambda_1)$ changes to the form,

$\lambda_2 - \lambda_1 = 0.305\ (t_{s_2} - t_{s_1}) + Cp\ (t_{s_1} - t_{s_2}) + Cp\ (t_2 - t_1)$. Wherein $Cp\ (t_2 - t_1)$ is the superheat and $(Cp - 0.305)\ (t_{s_1} - t_{s_2})$ is used in throttling.

As in the foregoing case,

$$\lambda_2 - \lambda_1 = \frac{W - V}{G}$$

therefore

$$Cp = \frac{(W - V) + 0.305\ G\ (t_{s_1} - t_{s_2})}{G\ [(t_2 - t_1) + (t_{s_1} - t_{s_2})]} \qquad (3)$$

From this equation Cp may be calculated. For $t_{s1} = t_{s2}$ we naturally obtain the simple formula

$$Cp = \frac{W - V}{G\,(t_2 - t_1)} \qquad (1)$$

Results of Tests: The tables and curves that follow are the results of 27 tests, which were executed between Aug. 9 and Nov. 30, 1905. They conclude a series of investigations covering a period of 2 years, comprising outside of many preliminary tests almost 100 complete working days, of which the last 27 were chosen for the determination of Cp.

Table I.

Results of Experiments by Knoblauch and Jakob at the Technical High School of Munich 1906.

Test No.	Pressure—Absolute		Temperatures		Specific Heat Cp.
	Kg. per sq cm.	Lbs. per sq in.	°C	°F	
1	2.01	28.59	149.1	300.4	0.478
2	2.02	28.73	188.2	370.8	.470
3	2.00	28.45	240.4	464.7	.474
4	2.00	28.45	245.9	474.6	.474
5	2.02	28.73	296.6	565.9	.476
6	2.01	28.59	345.9	654.6	.486
7	2.02	28.73	349.3	660.7	.494
8	4.00	56.89	170.6	339.1	.502
9	3.99	56.75	210.5	410.9	.490
10	4.01	57.03	260.8	501.4	.487
11	3.98	56.61	304.7	580.5	.485
12	3.98	56.61	306.1	583.0	.491
13	4.01	57.03	306.5	583.7	.490
14	4.00	56.89	350.3	662.5	.500
15	6.00	85.34	180.2	356.4	.531
16	6.00	85.34	217.5	413.5	.502
17	6.01	85.48	259.8	499.6	.492
18	5.98	85.05	306.4	583.5	.490
19	6.01	85.48	349.6	661.3	.502
20	8.00	113.78	188.1	370.6	.557
21	8.00	113.78	240.0	464.0	.500
22	8.00	113.78	295.0	563.0	.490
23	8.00	113.78	295.2	563.4	.488
24	8.00	113.78	295.7	564.3	.498
25	7.99	113.64	344.9	652.8	.501
26	7.98	113.50	349.8	661.6	.504
27	8.00	113.78	356.0	672.8	.509

Table I and the curves of Fig. 3 show the actual results of these tests. In the graphical interpretation of the results, care was taken that the deviation of the separate points from the compensating curve was as small as possible; on the other hand in drawing each separate curve, the direction of the other three curves was also taken into account. This consideration was advisable, as in the case at hand not only the graphical representation of the observations of equal pressure and varying temperature but also of equal temperature and varying pressure were to be shown. In drawing the curves a maximum deviation of 0.5% was allowed.

From the immediate results obtained for 2, 4, 6 and 8 atmospheres pressure, the curves for 1 and 0 and also for 10 atmospheres were easily obtainable by extrapolation. This was done in the following manner; from the Cp — t, diagram the values for Cp at a certain temperature were taken for various pressures and used in a Cp — p, diagram of isothermals. These isothermals were then extended from 2 to 0 and from 8 to 10 atmospheres; the values of Cp for the particular pressures were then finally again transposed to the Cp — t, diagram.

Later a further extrapolation to 20 atmospheres and 400° C. was attempted from which the curves of Fig. 4 have been transposed.

If at first sight such an extended extrtapolation may seem a venture, on closer investigation however of the following reasons they will deserve more confidence, and certainly for all practical purposes give sufficiently accurate values.

1. At saturation, where the change of specific heat with the pressure is especially large, and an extrapolation therefore could not be depended on, Cp may be fairly well determined by the equation

$$(Cp)_s = 0.41 + \frac{2.52 \cdot 10^8}{(T_k - T_s)^4} \qquad (4)$$

which gives exact values at saturation for 2, 4, 6, 8 and 207.1 Kg. per sq. cm. (i. e. the critical pressure). It may well be assumed therefore that the values thus obtained for from 8 to 20 atmospheres will not be much in error.

2. At high degrees of superheat (500 — 700° F) the specific

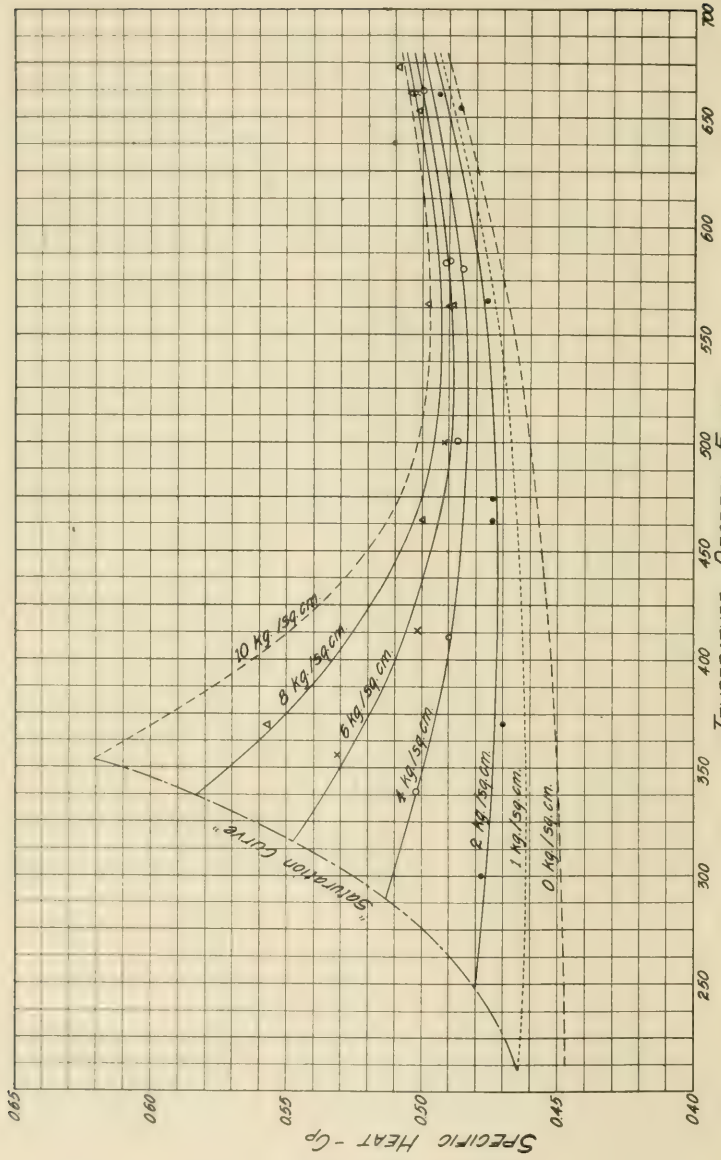


FIG. 3.—CURVES SHOWING VARIATION OF Cp WITH TEMPERATURE AND PRESSURE.

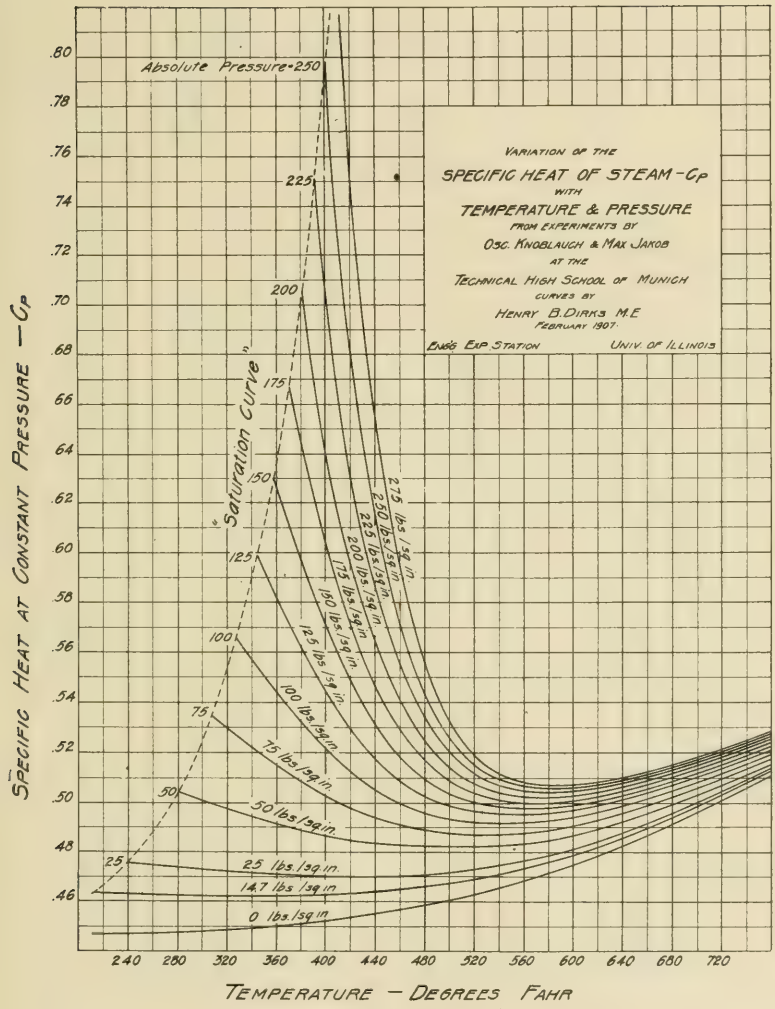


FIG. 4.

heat does not vary greatly with the pressure, see Fig. 3, so that an extrapolation would be sufficiently accurate.

There remains in doubt therefore, only the region from about 400 — 500°F. for which, however, the curves are almost rectilinear, and can therefore, be assumed with sufficient accuracy.

From Fig. 4 the mean specific heats for degrees of superheat

Table II.

Values of Mean Specific Heat Obtained From Curves of Fig. 4.

Pressure, lbs./□in. P—(Absolute)	14.7	25	50	75	100	125	150	175	200	225	250
Saturation Temp. t_s—°F	212.0	240.0	280.8	307.4	327.6	344.1	358.3	370.6	381.7	391.8	401.0
Temperature t—t_s °F	0.463	0.476	0.504	0.535	0.566	0.599	0.630	0.667	0.705	0.751	0.796
250	.462	.474	.....	.....	.....	.....	.....	.....	.....	.....	.....
300	.462	.473	.499	.....	.....	.....	.....	.....	.....	.....	.....
350	.462	.473	.497	.525	.558	.592	.....	.....	.....	.....	.....
400	.462	.472	.493	.516	.541	.566	.594	.628	.662	.714	...
450	.462	.471	.490	.509	.527	.547	.567	.588	.608	.635	.667
500	.463	.471	.488	.504	.518	.533	.547	.561	.574	.591	.609
550	.464	.471	.487	.500	.512	.524	.534	.544	.564	.566	.578
600	.465	.472	.486	.498	.508	.518	.526	.535	.541	.551	.540

from t_s, the saturation temperature, to a temperature t, which are of especial practical value have been determined and are recorded in Table II. These mean values were obtained by dividing the area below the curves of Fig. 4, as obtained with a planimeter, by the width, thus obtaining the mean height.

LAWS DEDUCED FROM EXPERIMENTS:

From the foregoing experiments it is evident that in regarding the variation of Cp the region near saturation must be considered apart from that at high superheat. The variations of the specific heat Cp with the temperature and pressure have been formulated by Knoblauch and Jakob into the following statements:

1. At constant temperature, Cp increases with increasing pressure. The rate of increase is greatest near saturation, decreasing at higher degrees of superheat.

1a. Near saturation the rate of increase of Cp with the pressure increases while at high superheat it seems to decrease.

2. For a given pressure Cp decreases with increasing superheat until reaching a minimum value after which it increases with the temperature.

2a. This minimum value changes at increasing pressure to higher temperatures.

3. The specific heat Cp for zero atmospheres is not a constant, as has usually been assumed, but increases at an increasing rate with higher temperatures.

4. The "saturation curve" rises with increasing temperature, therefore, also with increasing pressure, attaining very rapidly a large value of Cp.

This variation may be represented with comparative accuracy above 1 atmos. absolute by the empirical formula,

$$(Cp)_s = 0.41 + \frac{2.52 \cdot 10^8}{(T_k - T_s)^4} \qquad (4)$$

$T_k = t_k + 273 = 365 + 273 = 638°C.$, the critical temperature in absolute units.

$T_s = t_s + 273$, the absolute saturation temperature. This formula even holds at the critical, for which according to the theory of heat $Cp = \infty$. If we place $T_s = T_k$ in the above we obtain $Cp = \infty$. as required.

STRUCTURAL DESIGN OF ORDINARY BUILDINGS.

By Benjamin E. Winslow, M. W. S. S.

The structural design of buildings is a matter of the proper selection of loads and safe working stress, more than anything else. After the loads and safe working stresses are selected, almost everything else follows as a matter of course for ordinary buildings.

Most authorities agree on the formulae, by which the strength of beams should be calculated. Formulae based upon the common theory of flexure are almost universally used. Formulae for calculating the strength of columns vary greatly, but still the proper formula to use for any given case is well established, and in this paper no attempt will be made to cover this field, as it is well covered in the regular course of structural mechanics given at our universities. On the other hand, when we come to the proper selection of safe working loads, ultimate and safe working stresses and factors of safety, there is altogether too great a variation to be found.

The minimum safe working live loads in lbs. per square foot of floor are often established by law. Thus, the ordinance of New York and St. Louis specifies 150 lbs. for the first floor of office buildings, while the ordinance of Milwaukee specifies 60 lbs., For schools, the ordinances of Boston and Baltimore specify 150 lbs., while the Milwaukee ordinance specifies 50 lbs., and for warehouses the ordinance of Boston specifies 250 lbs., while the Chicago ordinance specifies only 100 lbs. Such a wide range of the minimum live loads allowed for buildings used for the same purposes, but located in different cities, is unwarranted, and only causes contempt for the ordinances, and does a great deal of harm.

A similar wide range is required by law for the safe working stresses for the same materials. For the extreme fiber stress in compression of cast iron, the Boston ordinance specifies 8000 lbs.

per square inch, while the New York ordinance allows 16000 lbs. The stress on the extreme fiber of yellow pine beams is limited to 1200 lbs. per square inch in New York, while 1800 lbs. per square inch is allowed in Buffalo and Memphis, Tennessee. The safe compressive strength of oak across the grain is limited to 250 lbs. per square inch in Chicago, while 800 lbs. per square inch may be used in New York and Washington.

The ultimate strength as given by various authorities causes a great deal of confusion. For the modulus of rupture for long leaf Southern pine, Prof. Lanza gives 5000 lbs. per square inch, while Prof. Patton gives 15000 lbs. For the ultimate shearing strength of oak parallel with the grain, Prof. Lanza gives 266 lbs. per square inch; A. L. Johnson and W. G. Berg give 800; Professors Fernow and Burr give 1000; Prof. Hatfield, 1250; and Prof. Patton, 2300 lbs. per square inch,—a variation of over 800 per cent!

The safest course is to find out the reliability of the tests quoted by the various authorities, and if they are equally reliable, to take a grand average of them all; it may, therefore, be very misleading to fall back on one authority alone.

The factor of safety may be defined as the ratio of the *ultimate stress* to the safe stress. As both the numerator and denominator of this ratio are thus seen to vary between wide limits, the factor of safety naturally will also have a large variation. This variation is increased by many other uncertain factors that enter into the factor of safety. Broadly speaking, the factor of safety depends upon the following three factors, namely:

1. The nature of the load
2. The nature of the material
3. The nature of the structure.

The first step in determining the factor of safety is to find out what loads will have to be provided for. The loads include the dead loads, or the weight of the structure itself; and the live loads, which latter may be static loads, or moving loads that may or may not be applied suddenly, or with impact. Wind loads and centrifugal loads would also come under this heading. As the amount of the loads may vary between wide limits, the next step would

be to determine for the given case, the probable maximum load which should be used in connection with the ordinary safe working stresses and safe limits of deflection. The next step would be to determine whether or not still larger loads would be possible although improbable. For such loads the ordinary safe working stresses may be increased 25 per cent. For improbable but absolute maximum congested loads of short duration only, the safe working stresses could be increased 50 per cent, provided the stresses still remain well within the elastic limit of the material. It should also be borne in mind whether or not any future use, that the building might be put to, would call for larger loads still. The above arrangement is perfectly logical, and is recommended by Mr. C. C. Schneider, past President of the American Society of Civil Engineers.

The second item that enters into the make up of the factor of safety is consideration of the nature of the materials. This would include the range of strength that the given material has in tension, compression, transverse bending and shear, the modulus of elasticity, the modulus of resilience, the elastic limit, the coefficient of expansion, the size of test pieces that the above values are based upon, the percentage of moisture of timber, and its influence on its strength, the quality of the material, and the influence of probable defects such as knots and season checks in timber, blowholes in castings, probable inequalities in cement and steel and deterioration of stone due to influences of the weather, and other seen and unseen defects that are likely to occur. To this must be added the consideration of the liability of timber to rot, and of steel and iron to corrode as well as the influences of intense heat or cold if probable.

The third item that enters into the make up of the factor of safety is the nature of the structure, whether temporary or permanent, important or unimportant, and the possible damage that may be caused by failure, and whether or not such failure may occur with or without warning. The stiffness or rigidity of the structure should also be considered as an element equally important as that of the strength. Arrangements should be made that certain limits of deflection are not exceeded, and it should be seen that such deflections do not produce secondary stresses difficult

to compute, and also that the lateral stiffness of joists, beams, girders and columns is properly looked after. Scantness in the size of joists and timbers and probable imperfections in workmanship are often loaded on the factor of safety.

For special constructions as, for example, long span segmental hollow tile arches, it should be ascertained whether or not the factor of safety is based upon a uniform load distributed over the whole span of the arch, as is often wrongfully done, or whether it is based upon a load that covers half the span only as the worst probable loading. It should also be seen that the tie rods are not spaced too far apart or perhaps entirely omitted.

The factor of safety for reinforced concrete is furthermore loaded with the uncertainties dependent upon the mixing and placing of the materials. The ordinary assumed bending moments for continuous slabs and girders are often only one half of the actual bending moments that may be developed by special loadings covering one panel at a time and larger bending moments still are often caused by very small uneven settlements. The effect of the too early removal of the forms or support is also often left to the factor of safety to take care of. All of these elements are generally loaded on the factor of safety which too often is taken at the lowest possible limit. When the factor of safety becomes overloaded a failure is sure to occur, and when it does occur, it often happens that nobody is able to locate the cause.

We will thus see that when the factor of safety, or the ratio of the *ultimate stress* to the safe stress is taken to be say 4, this does not by any means mean that it will be possible to put 4 times the calculated load on the structure before failure will take place, as is often believed. The failure will undoubtedly take place under much smaller loads. Too often, the factor of safety is a matter of guesswork, pure and simple. Great sums of money are annually wasted by an improper guess at this factor, and on the other side, a number of buildings are standing up that should fall down; the chances are that such buildings may be standing, because they have not happened to have received the loads they may be subjected to at any time.

There is a great need for the establishment of a more rational method for taking care of all of these variable elements, so as

to be able to design safe buildings with a minimum amount of cost.

The following method, embodied in tables 1 to 10 inclusive, is offered for consideration, by which it will be shown clearly how the variable elements are provided for, and also what elements should, and should not, be included in the selection of the factor of safety proper:

TABLE I.

FACTOR OF SAFETY FOR GOOD ORDINARY BUILDINGS.

The Factor of Safety is the sum of the values of the separate items which enter into the make-up of the Factor of Safety. These items and their values are as shown below:	Timber	Wr. Iron or Steel	Cast Iron	Masonry
Absolute Minimum Factor of Safety to be allowed for temporary buildings of good ordinary Materials and Workmanship.....	3	2	5	8
For Permanent Structures, Add	1	1	1	1
For Important Structures where great damage may result from failure, Add..... ..	1	1	2	3
If failure may occur without warning, Add....	1	1	2	3
If loads are only approximately correct, Add..	1	1	1	2
If the Timber is green or moist, Add.....	1	..	..	..
If the strength of timber is based upon tests of small size, Add.....	1	..	..	..
It the Timber is likely to rot, if the Iron or Steel is likely to corrode, or if the Stone is likely to deteriorated, Add.....	2	1	1	3
If the Workmanship is second class, Add.....	1	1	1	1

Table II.

Ultimate and Safe Strength of Metals in Pounds Per Square Inch.

Material	Compression			Safe Bearing	Shear			Modulus of Elasticity		Weight per Cubic Foot
	Ultimate		Safe		Ultimate		Safe	Ultimate		
	From	To	Av.		From	To	Av.	From	To	
Hard Steel	36000	40000	18000	26000	45000	55000	12000	28,000,000	31,000,000	490
Medium Steel	33000	38000	16000	24000	50000	60000	12000	28,000,000	31 000,000	490
Steel Pins	33000	38000	16000	24000	50000	60000	12000	28,000,000	31,000,000	490
Steel Shop Rivets	24000	29000	16000	24000	50000	60000	12000	28,000,000	31,000,000	490
Steel Field Rivets	24000	29000	12000	18000	50000	60000	9000	28,000,000	31,000,000	490
Wrought Iron	25000	35000	12000	18000	35000	45000	9000	25,000,000	29,000,000	480
Wrought Iron Bolts	25000	35000	12000	18000	35000	45000	9000	26,000,000	30,000,000	480
Maleable Iron										
Cast Steel	60000	90000	18000	26000	50000	60000	2000	29,000,000	32,000,000	490
Cast Iron	60000	90000	12000	15000	15000	25000	2500	12,000,000	18,000,000	450

Material	Extreme Fiber Stress			Tension			Elastic Limit		Modulus of Resilience
	Ultimate		Safe	Ultimate		Safe	Ultimate		
	From	To	Av.	From	To	Av.	From	To	
Hard Steel	50000	70000	18000	65000	75000	18000	35000	45000	35
Medium Steel	40000	60000	16000	60000	70000	16000	30000	40000	35
Steel Shop Pins	40000	60000	24000	60000	70000	16000	30000	40000	35
Steel Shop Rivets	40000	60000	24000	48000	58000	None	24000	30000	35
Steel Field Rivets	40000	60000	18000	46000	54000	None	24000	30000	13
Wrought Iron	30000	50000	12000	45000	50000	12000	25000	35000	13
Wrought Iron Bolts	30000	50000	18000	45000	55000	12000	25000	35000	13
Maleable Iron									
Cast Steel	60000	90000	18000	60000	75000	18000	35000	50000	
Cast Iron	30000	40000	3500	15000	25000	3000	10000	20000	1.2

Table V.

Ultimate and Safe Strength of Concrete in Pounds Per Square Inch.

Modulus of Elasticity of P. C. Stone Concrete 1:2:4 60 Days Old for Various Stresses	Modulus of Elasticity	Strength of 1:2:4 P. C. Stone Concrete for Various Ages	Compression on Top Fibers of Beams			Modulus of Elasticity	
			Ultimate		Safe	Ultimate	
	Ultimate		From	To	Av.	From	To
Initial Mod. of Elasticity....	2,000,000	1 Day Old	200	300	0		
E. for Stress of 400 lbs pr. "	1,700,000	2 " "	400	700	100		
" " " 600 " "	1,600,000	4 " "	600	1000	200	800,000	1,300,000
" " " 800 " "	1,500,000	7 " "	900	1500	375	1,200,000	2,000,000
" " " 1000 " "	1,400,000	1 Month Old.....	1200	2000	500	1,600,000	2,600,000
" " " 1200 " "	1,300,000	2 " "	1400	2300	575	1,800.000	3,000,000
" " " 1400 " "	1,100,000	3 " "	1500	2500	625	2,000,000	3,300,000
" " " 1600 " "	900,000	6 " "	1600	2700	675	2,200,000	3,600,000
" " " 1800 " "	600,000	1 Year Old.....	1700	2900	725	2,300,000	3,800,000
E. for Ultimate Strength....	0	2 " "	1800	3000	750	2,400,000	4,000,000

Table III.

Ultimate and Safe Strength of Wood in Pounds Per Square Inch.

MATERIAL	Extreme Fiber Stresses			Compression with the Grain			Compression Across the Grain			Modulus of Elasticity		Weight per Cubic Foot	
	Ultimate		Safe	Ultimate		Safe	Ultimate		Safe	Ultimate			
	From	To	Av.	From	To	Av.	From	To	Av.	From	To	From	To
Long Leaf Pine	7000	14000	1500	6000	9000	1500	1000	2000	350	1,500,000	2,250,000	40	50
Oregon Pine	7000	13000	1400	6000	9000	1400	900	1800	300	1,400,000	2,100,000	35	45
White Oak	6000	12000	1300	5000	8000	1300	1500	3000	500	1,300,000	1,950,000	45	55
Short Leaf Pine	6000	11000	1200	5000	8000	1200	900	1800	300	1,200,000	1,800,000	35	45
Spruce	5000	10000	1100	4000	7000	1100	800	1600	250	1,100,000	1,650,000	30	40
Norway Pine	5000	9000	1000	4000	6000	1000	700	1400	200	1,000,000	1,500,000	30	40
White Pine	4000	8000	900	4000	6000	900	600	1200	200	900,000	1,350,000	25	30
Fir	4000	7000	800	3000	5000	800	600	1200	200	800,000	1,200,000	25	30
Hemlock	3000	6000	700	3000	4000	700	600	1200	200	700,000	1,050,000	25	30
Cedar	3000	5000	600	3000	4000	600	500	1000	200	600,000	900,000	20	25

MATERIAL	Shear with the Grain			Shear Across the Grain			Tension with the Grain			Elastic Limit		Modulus of Resilience
	Ultimate		Safe	Ultimate		Safe	Ultimate		Safe	Ultimate		
	From	To	Av.	From	To	Av.	From	To	Av.	From	To	
Long Leaf Pine	400	800	150	4000	6000	1000	8000	15000	1700	6000	12000	3.0
Oregon Pine	400	700	140	4000	5000	900	8000	14000	1600	6000	11000	3.0
White Oak	400	1000	200	4000	6000	900	7000	14000	1500	5000	11000	3.0
Short Leaf Pine	350	700	120	3000	5000	800	7000	13000	1400	5000	10000	2.5
Spruce	300	600	110	3000	4000	800	6000	12000	1300	4000	9000	2.5
Norway Pine	300	600	100	3000	4000	700	6000	11000	1200	4000	8000	2.5
White Pine	300	600	90	2000	3500	600	5000	10000	1100	3500	7000	2.0
Fir	250	500	80	2000	3000	500	5000	10000	1000	3000	6000	2.0
Hemlock	200	400	70	2000	3000	500	4000	9000	900	2500	5000	2.0
Cedar	200	400	60	2000	2500	400	4000	8000	800	2500	4500	1.5

Table IV.

Ultimate and Safe Strength of Masonry in Pounds Per Square Inch.

MATERIAL	Compression			Safe Bearing	Modulus of Elasticity		Shear			Tension			Weight per Cubic Foot	
	Ultimate		Safe		Ultimate		Ultimate		Safe	Ultimate		Safe		
	From	To	Av.		From	To	From	To	Av.	From	To	Av.	From	To
Hard Brick Work in P. C.	2000	3000	200	275	1,500,000	2,500,000	.....	.....	.....	100	200	20	130	150
Common " P. C.	1500	2500	175	250	1,500,000	2,500,000	150	300	20	100	200	20	110	130
" " N C.	1000	2000	150	200	1,000,000	1,500,000	.....	.....	.....	50	100	10	110	130
" " L. M.	800	1600	100	150	500,000	1,000,000	.....	.....	.....	20	40	5	110	130
" " P.C. & L.M.	1000	2000	150	200	1,000,000	1,500,000	.....	.....	.....	50	100	10	110	130
Old Brick Work in P. C.	2000	3000	200	275	2,000,000	3,000,000	.....	.....	.....	120	250	25	110	130
" " " N. C.	1500	2500	175	250	1,500,000	2,000,000	.....	.....	.....	70	120	15	110	130
" " " L. M.	1000	2000	150	200	1,000,000	1,500,000	.....	.....	.....	25	50	7	110	130
Brick Piers in P. C.....	1500	2500	175	250	1,500,000	2,500,000	.....	.....	.....	100	200	20	110	130
" " L.M.....	800	1600	100	150	500,000	1,000,000	.....	.....	.....	20	40	5	110	130
Rubble Work in P. C...	1000	2000	150	200	1,500,000	2,500,000	.....	.....	.....	70	150	20	130	150
Coursed Rubble in P. C..	1500	2500	175	250	2,000,000	3,000,000	.....	.....	.....	100	200	20	140	160
Neat P. C.....	2000	4000	200	300	1,500,000	3,000,000	1200	2400	300	400	800	70	80	90
Neat N. C.....	1000	3000	175	250	1,000,000	2,000,000	700	1500	125	200	400	30	60	70
P. C. Mortar 1 : 3	1500	2500	175	250	1,000,000	2,000,000	200	400	35	200	400	30	120	130
N. C. Mortar 1 : 2	800	1500	150	200	800 000	1,500,000	150	300	25	100	200	20	120	130
Lime Mortar.....	200	400	100	150	500,000	800,000	50	100	10	20	40	5	90	110
P. C. Stone Concrete 1:2:4	1500	3500	400	500	1,500,000	3,500,000	800	1200	125	200	400	40	140	150
N C. " " 1:2:5	1000	2000	200	300	1,000,000	2,000,000	500	1000	80	150	300	25	140	150
P. C. Cinder 1:2:5	800	1600	150	200	500,000	1,000,000	70	120	10	600	150	20	100	110
Granite	12000	20000	400	600	3,000,000	6,000,000	1200	2400	300	1200	2400	200	160	180
Limestone.	6000	12000	350	500	2,000,000	5,000,000	1000	2000	175	1000	2000	175	150	170
Sandstone.....	5000	10000	300	400	1,000,000	3,000,000	800	1600	125	800	1600	125	140	160
Brick and Tile.....	2000	5000	200	300	1,000,000	3,000,000	500	1000	80	500	1000	80	120	140

Table VI.
Bond and Diagonal Tension in Concrete.

MATERIAL	Bond or Adhesion			Diagonal Tension		
	Ultimate		Safe	Ultimate		Safe
	From	To	Av.	From	To	Av.
Plain Bars to P. C. Concrete.. ...	200	300	40	Values for		
Twisted Bars to P. C. Concrete....	250	450	90	diagonal		
Corrugated Bars to P. C. Concrete.	400	600	120	tension		
Tool Steel Bars to P. C. Concrete..	100	150	30	obtained		
Plain Bars to Cinder Concrete.....				by applying		
Portl. Cement to Brick	20	60	10	the formula		
Nat. " " "	15	40	7	$t = \frac{V}{b\,d'}$		
Lime Mortar " "	10	20	5			
Concrete 1:3:6				125	200	75

Table VII.
Safe Bearing Power of Soils.

CHARACTER OF SOIL	Pounds Per Square Ft.	
	From	To
Quicksand or Soft Clay.....	1000	2000
Ordinary Clay.....	3000	4000
Sand and Clay.....	3000	4000
Dry Sand.....	3500	6000
Dry Clay.....	4000	6000
Fine Course Sand.	4000	8000
Hard Clay.....	4500	8000
Fine Course Sand and Gravel...	5000	12000
Hard Pan.....	8000	12000

Table VIII.

Floor Loads for Buildings of Ordinary Construction.

KIND OF BUILDING	Dead Load		Live Load		Total Load	
	From	To	From	To	From	To
Plastered Ceilings	10	15	0	10	10	25
Shingle Roofs, Skylights	10	15	25	30	35	45
Slate, Tile or Flat Gravel Roofs	15	25	25	30	40	55
Country Houses	15	20	40	50	55	70
Dwellings, Residences, Boarding and Lodging Houses	15	20	40	60	60	80
Apartment and Tenement Houses	15	20	40	60	60	80
Hotels, Office Buildings, Hospitals	15	20	50	70	65	90
Schools, Colleges and Dormitories	20	25	50	70	70	95
Porches and Verandas	15	20	70	90	85	110
Private Stables and Carriage Houses	20	25	80	100	100	125
Ordinary and Department Stores	20	25	80	100	100	125
Tailor Shops and Shops for Light Work	20	25	80	100	100	125
Churches and Theaters with Fixed Seats	20	25	80	100	100	125
Light Manufacturing Buildings	20	25	80	100	100	125
Lobbies and Stairs in Public Buildings	20	25	80	100	100	125
Firescapes and Balconies	15	20	100	120	115	140
Public Libraries, Armories, Grand Stands	20	25	100	120	120	145
Floors Stablerooms for large Livery Stables	20	25	100	120	120	145
Furniture and other light Storage	20	25	100	120	120	145
Light Printing Establishments and Footways for Highway Bridges	20	25	100	120	120	145
Court Houses, City Halls, Jails	20	25	100	120	120	145
Assembly Halls without fixed seats, Haylofts	20	25	100	120	120	145
Dancehalls, Drillhalls and Gymnasiums	20	25	120	150	140	175
Factories for heavy work, light Warehouses	20	25	120	150	140	175
Merchantile Buildings	20	25	150	200	170	225
Light Machinery, ordinary Warehouses	25	30	150	200	175	230
General Teaming with Trucks	20	30	200	250	220	280
Sidewalks	100	120	200	250	300	370
Heavy Storage, Power Houses, Foundries	30	40	200	400	230	440
Alley Driveways	100	150	250	300	350	450
Storage of Paper, Heavy Warehouses	30	40	300	500	330	540
Heavy Machinery, Printing Presses	30	40	400	500	430	540
Horizontal Wind for all Buildings more than $1\frac{1}{2}$ x the width in height						25

Table IX.

Special Loads and Weights of Building Materials.

	Total Weight	Concentrated Load	Load pr. Square Ft.	Load pr. Lineal Ft.	Load pr. Cub Ft.
Heavy Machinery and Heavy Safes			Actual Weight		
Heaviest Portable Safes	16000				
Coal Wagons	16000	4000			
Automobiles	6000	1500			
Ordinary Safes for Offices	5000	4000			
" " " Dwellings	2000	1500			
Cases with Drawers					20
Book Cases for each foot in height			25 30	25-30	25 30
Book Cases, f.e. Ft. in Ht. on each side of partition			25-30	50 60	25-30
Pianos.....from	800 to 1200				
Furniture in Dwellings, maximum			10		
4" Partition, Stud. plastered 2 sides			15		
6" " " " " "			20		
Grain					48
Hay					18
Oats					24
Snow, freshly fallen					12
" wet					48
Plastering—Cement Floor					90-110
Asphalt Flooring					80-100
Tile Flooring					140-160
Terra Cotta Fasing, hollow, 4" thick					80 100

Thickness of flat Tile Arch	6"	7"	8"	9"	10"	12"	15"	16"
Weight per cu. ft.	23–27	25–30	26 30	27-33	28-35	30-40	42-52	42-52
							Furr.	Tile
Thickness of Tile..... Partition.....	2"	3"	4"	5"	6"	8"	1½"	2"
Weight pr. Sq. ft.	10–12	13-16	15-18	17-20	20-24	25-30	7	8
Thickness of Book Tile	2"	2½"	3"	3½"	4"			
Weight per Sq. ft.	9–10	11–13	13–17	15-18	17-20			

WEIGHT OF A CROWD OF PEOPLE; EACH PERSON WEIGHING 150 LBS. [CREHORE]

Distance apart, ctr.—ctr.	12"	13"	14"	15"	16"	17"	18"	19"	20"	21"	22"	23"	24"
Weight pr. Sq. ft.	150	127	110	96	84	75	66	59	54	49	44	40	37½

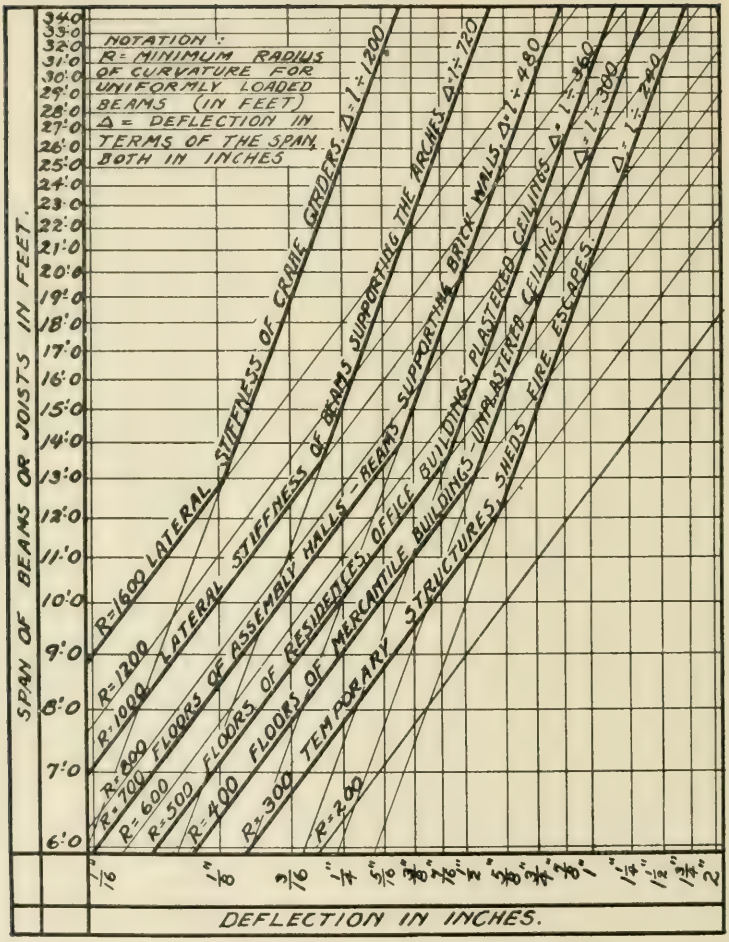

NOTATION:
R = MINIMUM RADIUS OF CURVATURE FOR UNIFORMLY LOADED BEAMS (IN FEET)
Δ = DEFLECTION IN TERMS OF THE SPAN, BOTH IN INCHES
SPAN OF BEAMS OR JOISTS IN FEET.
R=1600 LATERAL STIFFNESS OF CRANE GIRDERS. Δ = 1/1200
R=1400 LATERAL STIFFNESS OF BEAMS SUPPORTING THE ARCHES Δ = 1/720
R=1200 LATERAL STIFFNESS OF HALLS - BEAMS SUPPORTING BRICK WALLS Δ = 1/480
R=1000 FLOORS OF ASSEMBLY BUILDINGS, PLASTERED CEILINGS Δ = 1/360
R=800 FLOORS OF RESIDENCES, OFFICE BUILDINGS - UNPLASTERED CEILINGS Δ = 1/300
R=700 FLOORS OF MERCANTILE BUILDINGS - UNPLASTERED CEILINGS Δ = 1/240
R=600 TEMPORARY STRUCTURES, SHEDS FIRE ESCAPES
R=500
R=400
R=300
R=200
DEFLECTION IN INCHES.

TABLE X.—ALLOWABLE DEFLECTION OF BEAMS.

Notes: As the deflection of beams permanently loaded increases with time, beams carrying brick walls should be figured stiffer than ordinary floor beams.

The heavier the floor, the greater may be the allowable deflection, as a heavy floor is better able to resist shocks or vibrations than a lighter one.

Table 1 is based upon the theory that definite values be given to the various elements that enter into the make up of the factor of safety. Table 1 covers variations in the nature of the structure and in the nature of the materials insofar as they are not covered by tables 2 to 7. For a given case the various items on table 1 should be noted and the values of the various items added together. The sum of these items will then give the factor of safety that should be used for the case in hand. The working stresses can then be obtained by dividing the ultimate stress by the factor of safety thus found.

For ordinary buildings of good ordinary materials and workmanship, the following factors of safety will be obtained from table 1:

For timber	from 4 to 6
For wr. iron and steel	from 3 to 4
For cast iron	from 6 to 8
For masonry	from 8 to 12

which conforms with good practice. This method has the additional advantage that it can be seen at once what the factor of safety does take care of. Tables 2 to 7 will cover variations of the material and give the range of strength that could be expected of good ordinary materials and workmanship. Inferior materials will come below the lowest limits given on these tables, and superior materials will come above the highest limits. The safe compressive unit stress to be used for long columns should be obtained from the use of some approved column formulae, which also should take care of possible eccentric applications of the load.

The safe extreme fiber stress for long narrow beams and girders, including plate girders, not braced sideways, should also be obtained from some approved column formulae. In this manner the lateral strength of beams is provided for.

The factors of safety obtained from tables 1 and 2 will hold good for the probable maximum loads that the structure will have to carry. Such loads are given on table 8. For possible but improbable loads the safe working stresses could be increased 25 per cent. For possible but improbable absolute maximum load of short duration the safe working stresses could be increased 50 per cent, provided the stresses remain well within the elastic limit of

the material. This will take care of concentrated heavy loads and occasional loads applied suddenly or with impact.

Smaller loads than the minimum, given on table 8 should never be used, even for cheap buildings, while the larger loads will unquestionably give first class buildings. The weights of materials are given on tables 2, 3 and 4, and special loads that it may be necessary to provide for are shown on table 9.

The probability that all parts of the structure will receive the full amount of the live load is not the same. Thus a joist may very likely receive the full live load, but the probability that a girder will receive it is less, and the probability that a column in the lower story of a many story building will receive it, it still less, and the foundation will have a smaller chance than any other part of the building of receiving the full calculated live load from every square foot of the floor area of the building. It is customary to allow for this in the loading. The following method is believed to conform with good practice:

Figure all parts of the building for the full dead load.

Figure joists and beams for the full live load.

Figure girders for 85 to 90 per cent of the live load.

Figure the columns supporting the roof and top story of a building for the full live load. For each succeeding story below, make a reduction of 5 per cent in the full live load coming on the columns. This reduction must, however, not exceed 50 per cent of the full live loads for a many story building. Figure the foundation for one-third of the full live load. On table 5 may be found the safe pressures that may be allowed on various kinds of soils when the loads are calculated as outlined above. The lower values hold good for such poor soils as those found in Chicago. Of course, if it is known that the beams, girders, columns and foundations will have to carry the full live load, they should be figured strong enough to carry it with the proper factor of safety. In this manner all variations in the load are provided for.

Finally on table 10 is given the safe allowable deflections for structures of various kinds. In calculating the deflection, the values for the modulus of elasticity given on tables 2 to 7 should be used. As light floors may vibrate more and easier than heavy floors, a smaller deflection is allowed. As it is the actual curvature of the joists more than the actual deflection which causes

cracks in plastered ceilings, such joists should be figured for curvature when the radius of curvature becomes small, which occurs for short spans.

Very short beams should be figured for shear or curvature; beams of intermediate spans should be figured for transverse strength; and beams of long spans should be figured for stiffness. Whether a beam for a given case should be figured for one or the other of the above factors, will depend much on the safe working stresses used as well as on the deflection, that may be allowed. When the deflection is 1-360th of the span, the beam uniformly loaded, the beam supported at both ends, the modulus of elasticity and the safe working stresses for shear and bending are as given on table 3, the following rules will be valid for any kind of wood:

1. Calculate for shear when the span is up to 12 times the depth of the beam, or when the depth of the beam in inches is greater than the span of the beam in feet.

2. Calculate for transverse strength when the span varies from 12 to 20 times the depth of the beam.

3. Calculate for stiffness when the span is greater than 20 times the depth of the beam.

Likewise, steel beams should be figured for deflection when the depth of the beam in inches, is less than twice the span in feet.

Tables 11, 12 and 13 give the position of the neutral axis, the effective depth and the strength of reinforced concrete beams and girders on basis of the formulae established by Professor Talbot. These formulae may be considered as the most scientific, most reliable thoroughly up to date and practical formulae yet devised, as they give the true stresses in the beam for all stages of the loading. They can be adapted for any factor of safety for strong or weak concrete, for beams of any age, and for beams of rectangular or tee section. Certain variations must be made if the steel is inserted in the top side of the beam. Of course, covering the ground in such an efficient manner, the algebraic expressions cannot be so very simple. However, when put in a diagramatic form, as on table 11, they will rival even the straight line theory in practicability and ease of application. Professor Talbot's formulae show just how reliable the straight line theory is for safe working stresses and how very far off the straight line theory is for ulti-

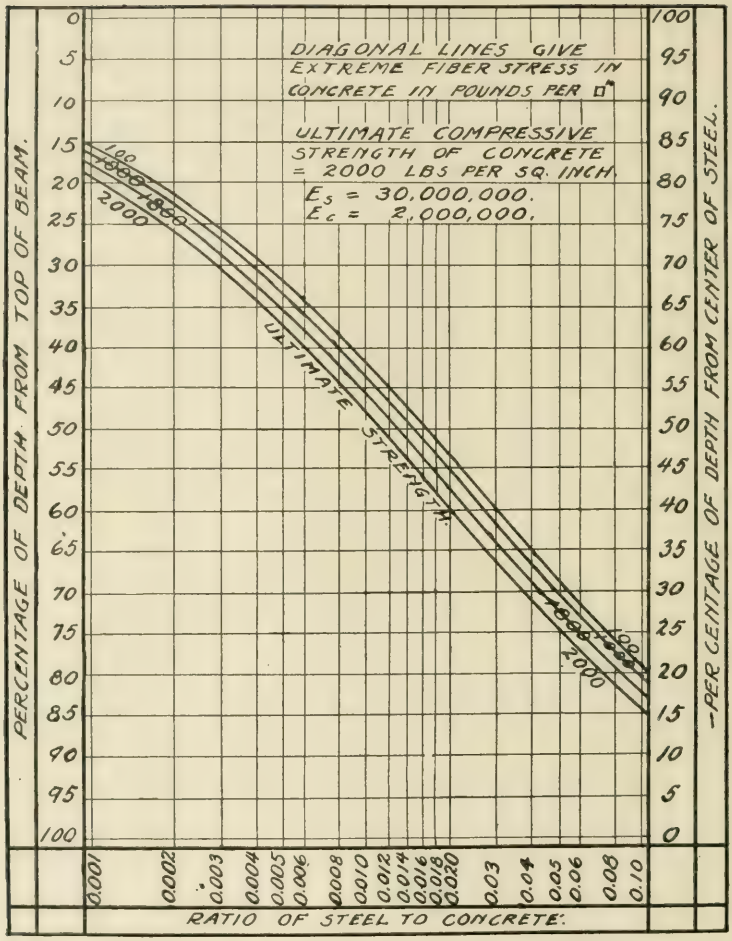

DIAGONAL LINES GIVE
EXTREME FIBER STRESS IN
CONCRETE IN POUNDS PER □"
ULTIMATE COMPRESSIVE
STRENGTH OF CONCRETE
= 2000 LBS PER SQ. INCH.
E_s = 30,000,000.
E_c = 2,000,000.
100
1000
1500
2000
ULTIMATE STRENGTH.
PERCENTAGE OF DEPTH FROM TOP OF BEAM.
PER CENTAGE OF DEPTH FROM CENTER OF STEEL.
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
0.001 0.002 0.003 0.004 0.005 0.006 0.008 0.010 0.012 0.014 0.016 0.018 0.020 0.03 0.04 0.05 0.06 0.08 0.10
RATIO OF STEEL TO CONCRETE.

TABLE XI.—POSITION OF NEUTRAL AXIS OF REINFORCED CONCRETE BEAMS.

Notes. This diagram is based upon Professor Talbot's formulae and shows how the location of neutral axis is lowered as the percentage of steel as well as the extreme fiber stress of concrete in compression is increased.

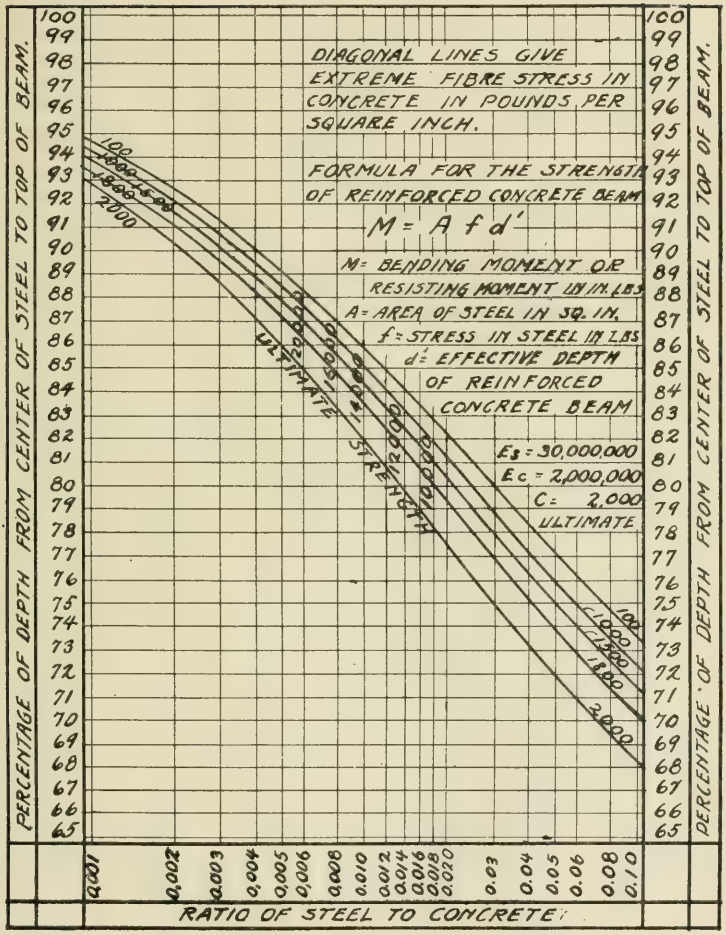

PERCENTAGE OF DEPTH FROM CENTER OF STEEL TO TOP OF BEAM.
DIAGONAL LINES GIVE EXTREME FIBRE STRESS IN CONCRETE IN POUNDS PER SQUARE INCH.
FORMULA FOR THE STRENGTH OF REINFORCED CONCRETE BEAM
M = A f d'
M = BENDING MOMENT OR RESISTING MOMENT IN IN. LBS
A = AREA OF STEEL IN SQ. IN.
f = STRESS IN STEEL IN LBS
d' = EFFECTIVE DEPTH OF REINFORCED CONCRETE BEAM
Es = 30,000,000
Ec = 2,000,000
C = 2,000 ULTIMATE
100
1000
1500
1800
2000
ULTIMATE STRENGTH
RATIO OF STEEL TO CONCRETE
0.001 0.002 0.003 0.004 0.005 0.006 0.008 0.010 0.012 0.014 0.016 0.018 0.020 0.03 0.04 0.05 0.06 0.08 0.10

TABLE XII.—EFFECTIVE DEPTHS OF REINFORCED CONCRETE BEAMS.

Notes:—This diagram is based on Professor Talbot's formulae and shows how the effective depth decreases as the percentage of steel and the extreme fiber stress in the concrete increase.

When the safe allowable extreme fiber stress in compresssion is assumed at 650 pounds per square inch, the stress in the steel will be as shown by the vertical figures across the curves.

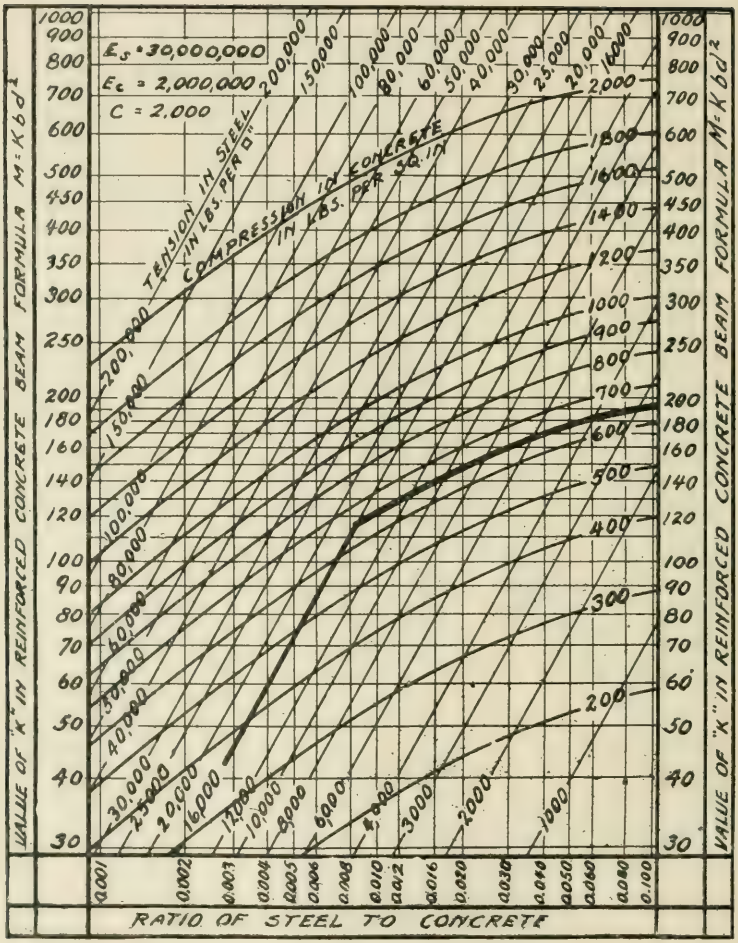

VALUE OF "K" IN REINFORCED CONCRETE BEAM FORMULA M=Kbd²
E_s = 30,000,000
E_c = 2,000,000
C = 2.000
TENSION IN STEEL IN LBS. PER □"
COMPRESSION IN CONCRETE IN LBS. PER □"
RATIO OF STEEL TO CONCRETE

TABLE XIII.—STRENGTH OF REINFORCED CONCRETE BEAMS.

mate loads. It shows that the strength line theory errs on the safe side for safe working stresses an amount of from 5 to 6 per cent only, and thus gives a strong argument in favor of the generally accepted methods of calculating reinforced concrete slabs and girders. Of course, Professor Talbot's method is the better of the two, as it may be used with confidence for any working stress, either safe or ultimate.

INDUCTION MOTORS IN CONCATENATION.

By V. L. Hollister, '07, Electrical Engineering

To understand the uses and advantages of the special connection of two or more induction motors, known as concatenation, it is necessary to consider the operating characteristics of such machines when operated as single units for the production of mechanical power. The induction motor consists of two windings on separate iron rings, the latter form the magnetic circuit and are mounted so that one revolves within the other. The flux produced by the coils on the outer iron ring pass out of their original ferric path across the air gap to the inner ring and back through the gap to the outer ring. Figure 1a shows the flux in a four pole motor. The dotted lines mark the lines of flux. Those marked A and B are produced by one phase of an alternating current, while C and D are produced by a current which is in time 90° out of phase with the first current as represented in figure 1b. Taking the conditions as they exist at the instant of time marked on the time magnitude curve as K K, the fluxes produced by A, B, C and D, are equal, since their magnetizing ampere turns are equal; the consequent north and south poles produced assume the positions as marked N and S. An instant later, marked T T on the curve, the magnetization marked I′, producing C and D, is reduced to zero; the current I″, producing A and B become a maximum, and the consequent poles are now in the position marked N′, S′. Following this operation for new positions of T T, as time advances, the poles S and N will be found to travel in a clockwise direction. Thus electrically we can produce a revolving magnetic field, it only remains to build such an inner ring that will be forced to follow the rotating magnetic field.

One of the fundamental laws of magnetism and electricity is that a closed electric circuit resists any force that tends to compel it to cut a magnetic flux. A coil of wire wound on the inner ring, when the latter is standing still, would cut the flux from each pole as it passes. According to the above law, closing the electric circuit will tend to stop this cutting of the flux, in consequence, the relative speed between the rotor and the magnetic field will be reduced, or, the rotor will assume almost the same

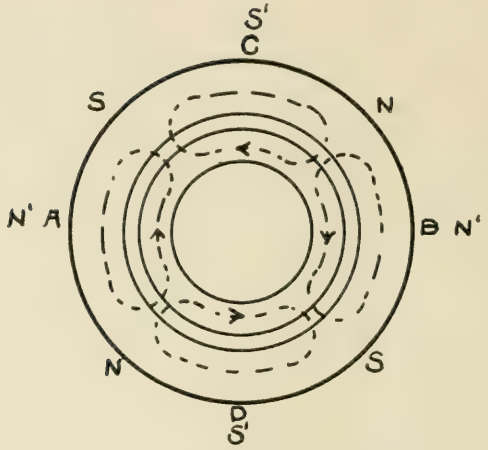


Fig. 1a

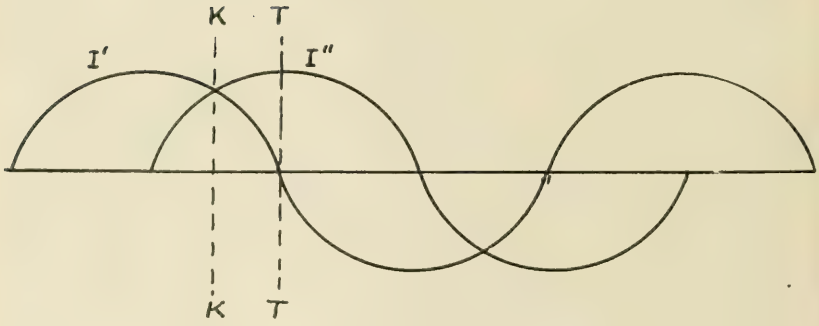


Fig. 1b

speed as the magnetic field. Perfect synchronism between the two speeds is impossible of attainment, however, since under that condition there is no cutting of the lines of flux by the secondary conductors; therefore there is no reaction between the primary and secondary windings. When the rotor of an induction motor is at standstill it affects its primary the same as a short circuited secondary of a transformer; synchronous speed corresponds to an open circuited secondary for a transformer. A motor, when unloaded, attains nearly to synchronous speed. The difference between the latter and the actual speed is just sufficient to pro-

duce enough electro motive force, current, and, therefore, reaction between primary and secondary to overcome the resisting friction, or load. This condition is true for all loads for which the rotor will run, and, thus, as the load increases, the difference between the two speeds increases. For low speeds and small outputs special arrangements are necessary, the most common of which is the introduction of resistance into the secondary circuit. Thereby the electro motive force and current necessary to produce the magnetic reaction between the primary and secondary is increased.

Incidental to this means of lowering the speed, however, is a very low efficiency, obviously a very unfavorable characteristic for an electrical machine. Reduction of speed, together with high efficiency, is the scope of tandem, or concatenated control of induction motors. The connection consists of leading the wires from the secondary of the first machine to the primary of motor number two. Figure 2 shows the connections necessary.

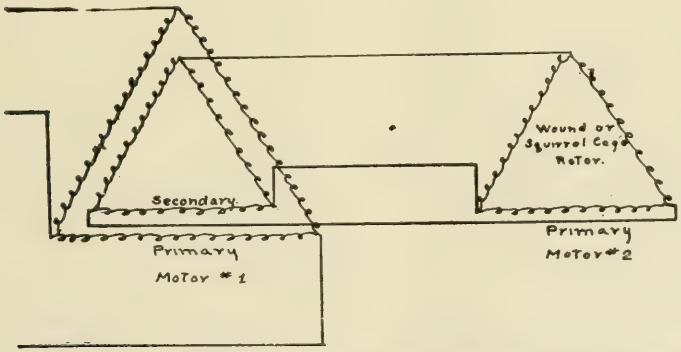


Fig. 2.—Diagram of Connections for Two Induction Motors.

Assuming that the first machine is at standstill and an alternating current is applied to the primary windings, from a knowledge of transformer action it is easily seen that an alternating current is induced in the secondary winding equal the primary current multiplied by the ratio,

$$\frac{\text{Primary turns,}}{\text{Secondary turns}}$$

and it can also be seen that this secondary current has the same frequency as the primary current.

Consider the effect produced in the second machine, where the voltage impressed is the original

$$\text{E. M. F.} \times \frac{\text{Secondary turns}}{\text{Primary turns}} \text{ of the first machine.}$$

The current is equal to that flowing in the secondary of the first machine. Thus the first motor is acting only as transformer, and if the secondary of motor number two is shortcircuited we shall expect it to assume full speed.

Now, turning to the theory of the rotating field of the induction motor, with the secondary of the first machine clamped stationary, its conductors are cut alternately by the lines of flux eminating from north and south poles. These poles follow each other in succession, any one of them making a complete revolution in $\frac{P}{fx60}$ th part of a minute. Where P is the number of pairs of poles and f is the frequency of the impressed voltage. Thus, with a six pole machine and a frequency of 60, the time of one revolution is $\frac{3}{60x60}$ $\frac{1}{1200}$ th part of a minute, or, N, the speed, is equal to 1200, this being the speed of the rotating field.

Let it be assumed that the secondary of the machine one is now released and is allowed to assume a speed of 300 revolutions per minute. It now has a speed of $1200 - 300 = 900$ R. P. M. relative to the rotating flux. Due to this new condition the frequency impressed on the second motor has changed and is $\frac{900}{1200} = 75\%$ of its former value, or, 45 periods per second. The speed of the second machine, dependent on the frequency impressed, has changed and is

$$N' = \frac{fx60}{P} = \frac{45x60}{3} = .900$$

Thus, we see that speeds of the two machines are inversely proportional and that the sum of the two speeds is equal to a constant, in this case— $300 + 900 = 1200$, neglecting slip.

It may be readily seen that by controlling the speed of the first motor by a brake, or otherwise, the speed of the second machine may be controlled through a wide range.

The most apparent drawback to this method of speed control is the large amount of turning effort exerted by the secondary of the first motor which must be overcome by a brake, or other contrivance. A natural means of applying a brake to the secondary of the first motor in order to vary its speed is at once suggested, viz., by placing a belt load on its pulley, driving a generator, or other load. Then, by varying the load so applied, the speed of the first motor may be varied, and inversely to such variation will the speed of the second motor be changed.

The factor entering into this operation which prohibits the low speeds of motor number two as well as the high speeds of motor number one is the voltage. From the equation of E. M. F. for a group of n conductors cutting a magnetic-flux Φ, $E = \frac{\Phi N n}{10^8}$ it is seen that the induced pressure is proportional to the speed N, or to the rate and number of times the conductors cut such field. With a revolving field the conductors cutting the flux will have the greater E. M. F. induced in them when moving at the greatest relative speed to the field, or when they have an absolute speed of zero. Thus, with the first secondary at standstill we have a maximum voltage impressed on the second primary, and with first machine at, or near, synchronism, the voltage impressed on the second primary will be very small.

From the foregoing it is seen that, if the rotating conductors have no speed relative to the revolving magnetic field, there is no E. M. F. generated in the secondary, since there is no cutting of the lines of force. Therefore, under these conditions, there is no current flowing in the secondary; there is no reaction between the secondary and the field, and the former tends to slow down. The condition of smaller secondary speed thus produced gives a relative speed between the magnetic field and the secondary, causing, thereby, a cutting of the flux, an E. M. F., and a current in the secondary. The resulting magnetic reaction between the rotating magnetic field and the secondary compels the latter to follow the former more closely. Following out these operations it is seen that a load on the secondary compels it to slow down, therefore a greater current is necessary to produce the required magnetic reaction between the secondary and the revolving field, and therefore greater cutting of lines by the secondary conduc-

tors to produce the larger E. M. F. and current in the secondary, therefore greater relative speeds between the field and secondary are found. This relative speed is called slip.

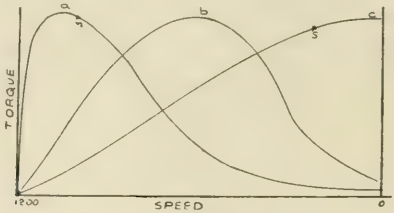


FIG. 3.—CURVES SHOWING RELATION OF SPEED TO TORQUE FOR DIFFERENT RESISTANCES.

Practical Application.—A railway operating on fairly steep grades is supplied a three phase current at high voltage. It is decided to use induction motors on the cars, one on each truck. The question of control involves the simple insertion of resistance into the secondary circuit, or tandem connections. We will compare the operating characteristics of the two systems.

Let the car be equipped with an arrangement to control the resistance of the secondary circuits of each motor. The curves of speed and torque are given in figure 3 for three different resistances in the rotor circuit. *a*, shows the speed torque curve for a very low resistance, practically that of the machine itself; *b*, shows a curve for the same motor with about twice the resistance used as for curve *a*; *c* is a similar curve for sufficient resistance inserted to produce maximum torque at standstill. It would seem as if with sufficient steps on the controller this method of control would be an ideal one—satisfactory in range and uncostly. The statement made above that the efficiency is extremely low at reduced speeds—applies here imperatively; in fact, prohibits its use. The greater the resistance in the secondary circuit the greater the losses, and the efficiency fall off in proportion to the speed. If the point *n* on the curve represents a point of operation at 90% efficiency, then *s* probably represents 1-5 of such efficiency, or less than 20%.

If the motors were arranged for concatenation the primary of the first machine be connected to the supply mains; its second-

ary would supply the primary of the second motor; and the secondary of the latter machine would be arranged so that different resistances could be inserted. Several steps on the controller would give a fine control of the speed of the motors up to one-half synchronism. The efficiency throughout this range of speed would vary from 65 to 85 per cent. From half synchronism to full speed the control must be by insertion of resistance in the rotor of each machine, the primaries being in parallel across the mains. By the above method the efficiency may be kept high and excellent control attained.

One advantage of the service assumed above, i. e., steep grades, is its braking action when forced above synchronism as a single motor, or above half synchronism for the concatenated couple. At such times the motors become asynchronous generators, supplying current to the line.

SOME CAUSES OF VIBRATION IN STEAM TURBINES.

By Kenneth G. Smith, '05, Mechanical Engineering.

The development of the direct connected steam turbine has made the question of high speed machinery an important one. And one of the most trying problems which confronts the builder of such machinery is that of vibration. The writer has been actively engaged during the past eighteen months in the building of steam turbines direct connected to fans, generators and pumps and the following observations are chiefly drawn from personal experience.

The leading causes of turbine vibration may be set down as follows:

1.—Critical speeds,
2.—Faulty balancing,
3.—Faulty alignment,
4.—Faulty lubrication,
5.—Uneven steam action,
6.—Individual peculiarities of a machine coming under any or all of the above classes.

The mathematical analysis of the subject of balancing and critical speeds would be out of place in an article of this character and will be but briefly touched upon.

In the first place it must be noted that there are certain speeds at which the rotor of the turbine or generator will vibrate no matter how perfectly balanced it may be. Above or below these speeds the rotor never can be (owing to its own weight if nothing else) on the true geometric axis of rotation. This being the case the center of gravity describes a small circle and the rotor is acted upon by a centrifugal force which tends to deflect the center of gravity more and more from the true axis of rotation. This goes on until the stresses in the shaft due to bending, just balance the centrifugal force. This is the critical speed.

Foster in his book on Steam Turbines and Turbo Compressors shows by a very simple demonstration that this speed exactly corresponds with the frequency of transverse vibration of the rotor.

Let W = Weight of rotor in pounds,
U = Deflection of center of gravity from geometric axis in feet,
N = Revolutions per second,
F = Force which will bend shaft one foot at center of gravity,

Then the center of gravity describes a small circle of radius U with a linear velocity in $\frac{\text{ft.}}{\text{sec.}}$ $V = 2\pi NU$

The force in the rotor tending to prevent bending is proportional to the deflection and therefore equal to FU. At the critical speed, as stated, this is equal to the centrifugal force so that

$$\frac{W}{g}\ \frac{V^2}{U} = FU$$

$$\frac{W}{g}\ 4\pi^2N^2U = FU$$

$$N = \frac{1}{2\pi}\sqrt{\frac{Fg}{w}}$$

If the rotor were vibrating transversely like a string or wire at the instant of passing through the axis the kinetic energy stored in the rotor would be

$$\frac{WV^2}{2g} = \frac{4\pi^2N^2U^2W}{2g}$$

This kinetic energy is equal to the work done in bending the shaft thru a distance U.
and therefore

$$\frac{4\pi^2N^2U^2W}{2g} = FU\ \frac{U}{2}$$

and

$$N = \frac{1}{2\pi}\sqrt{\frac{Fg}{w}}\ \text{as before}$$

At this critical speed we may conceive of the shaft as being bow shaped and revolving like a skipping rope held at the ends. This is the first critical speed. Other higher critical speeds occur at which the shaft vibrates in two, three, four or more loops varying with the disposition of the loads.

Foster shows further that as the deflection is proportional to the cube of the length and the critical speed inversely proportional

to the square root of the deflection, we may say that the critical speed is proportional to the $\frac{3}{2}$ power of the length. If the shaft vibrates in several loops the length, L may be L, $\frac{L}{2}$ $\frac{L}{3}$ $\frac{L}{4}$ $\frac{L}{5}$ and the critical speeds in the ratios 1, 2.7, 5.2, 8.0, 11.0

Returning to the formula for the critical speed, if we wish to express N in r. p. m. we have

$$N = \frac{60}{2\pi}\sqrt{\frac{Fg}{w}}$$

$$\text{or } N = 54.2\sqrt{\frac{F}{w}}$$

If we represent the deflection of the shaft at the center of gravity by U then

$$\frac{F}{W} = \frac{1}{U}$$

$$\text{and } N = 54.2\sqrt{\frac{1}{U}}$$

This formula may be used for finding the critical speed of a shaft loaded with several wheels provided we take U as the sum of the deflections caused by each individual wheel at its point of support.

An actual application of this formula may be of interest. A turbine with an unusually long shaft carried eight wheels, the sum of the several deflections being approximately 1/8".

$$N = \frac{54.2}{\sqrt{.282}} = 152.8 \text{ r. p. m.}$$

This turbine showed violent vibration at 200 r. p. m.

Under practical conditions turbines are run as far from critical speeds as possible. As a general rule the reaction turbines with their small radial clearances must be run below their critical speeds as the vibration at the critical speed would cause the rotor to strike the casing. Impulse turbines in which the radial clearances are large may be and usually are run beyond the critical speed as the momentary vibration at that particular point does no harm.

The subject of the critical speed, however, is one more particularly for the designer than for the builder, whereas the other causes of vibration enumerated must be eliminated so far as possible by the builder.

The matter of balancing is of paramount importance. Thin

disks may be given a static balance separately on a mandrel. This is rolled on hardened knife edges and metal is filed away on the heavy side until the disk balances. Thin disks may be balanced in this way but a heavy rotor must be given a rotative as well as a static balance. In doing this the rotor is rapidly whirled and a piece of chalk held near it while running. The side of the shaft which throws out is marked. This point is usually from 60° to 90° ahead of the actual heavy spot and at very high speeds even farther ahead.

When disks have been perfectly balanced statically it by no means follows that they will run in perfect balance. Owing to change of form caused by heating, a disk will sometimes cause a bad vibration after the turbine has been run for a time. Such troubles can only be remedied by rebalancing. One firm makes a practice of running its turbines and then rebalancing the disks. In one case which came under the writer's notice, the individual disks were in apparently perfect balance whereas the whole rotor would vibrate periodically. This trouble was remedied by interchanging two disks. Vibration caused by faulty balancing may be distinguished by the heavy jar communicated to casing, bed plate and foundation, which grows worse and worse as the speed increases.

If in the case of direct coupling either turbine or generator is slightly out of balance the vibration may increase and decrease in well defined periods sometimes with an unpleasant humming noise, the periods becoming shorter and shorter as the speed increases until both series merge into one continuous jar.

Another cause of vibration is that of poor alignment either in the machine itself, or if coupled direct, between the turbine and the driven machine. This is not so simple a matter as it would seem at first thought for several reasons. Two shafts in perfect alignment when standing very often will not be so when rotating at a speed of 3000 r. p. m. Allowances also must be made for heat expansion so that two machines cannot be in alignment when cold if they are to be in line under operating conditions. Such things as warped bed plates, settling foundations, etc., also occur. Two companies, the DeLaval and the General Electric, use a flexible coupling to avoid troubles of this kind. Poor alignment in the machine itself, that is a warped or crooked shaft is apparent at once by a loud humming noise and a jar though not so heavy as that caused by an

unbalanced rotor. Very often this vibration occurs in distinct periods, the shaft apparently lifting and rolling in its bearing. If shafts are turned to size drilled and placed at once in the turbine, springing due to the heating by the steam is almost certain to occur. To avoid this difficulty, the shafts are turned, heated for a time, drilled or keyseated and then turned to size and finished. Sometimes more than one heating is necessary. A shaft so little out of true that it apparently runs perfectly at 1200 r. p. m., will make trouble at speeds from 1800 to 3600 r. p. m. The point at which a crooked shaft begins to vibrate is usually very marked and from that point on the vibration increases with the speed.

Vibration from faulty lubrication does not cause a heavy jar or humming noise. It may be felt as a peculiar shiver running through the machine, chiefly in the shaft and bearings of course. Such vibration when marked and continuous is usually the precursor of a hot bearing unless the trouble is remedied. Slight vibrations of this kind are often present in a new machine and gradually die away as the bearings and shaft settle into place. If they do not, examination of the bearings will usually show high spots or other marks of poor lubrication. Poor oil or oil too light for the heat or pressure will cause the same trouble.

Two or three instances of vibration apparently caused by uneven steam action have come to the writer's notice. In all cases the vibration of the shaft was endwise and not transverse. On examining the turbine it was found that some of the buckets not being exactly in line with the impinging jet caused a rapidly alternating end thrust as the rotor came up to speed. This vibration was much more marked at low than at high speeds.

The remedy for the vibration is naturally suggested by the cause, but it must not be supposed that these various causes are independent of each other. In fact vibration will be found due to several of these causes acting together; for instance, faulty alignment may cause poor lubrication and vibration arise from the two causes. It may be added too that when vibration begins, poor lubrication follows as the oil film on the shaft is broken and it no longer floats smoothly in the bearing.

The problem is at best a perplexing one and the high speed engineer and turbine builder must constantly bear in mind the fact that matters considered of small moment at speeds of 900-1200 become of vastly greater import at speeds of 2400 and upwards.

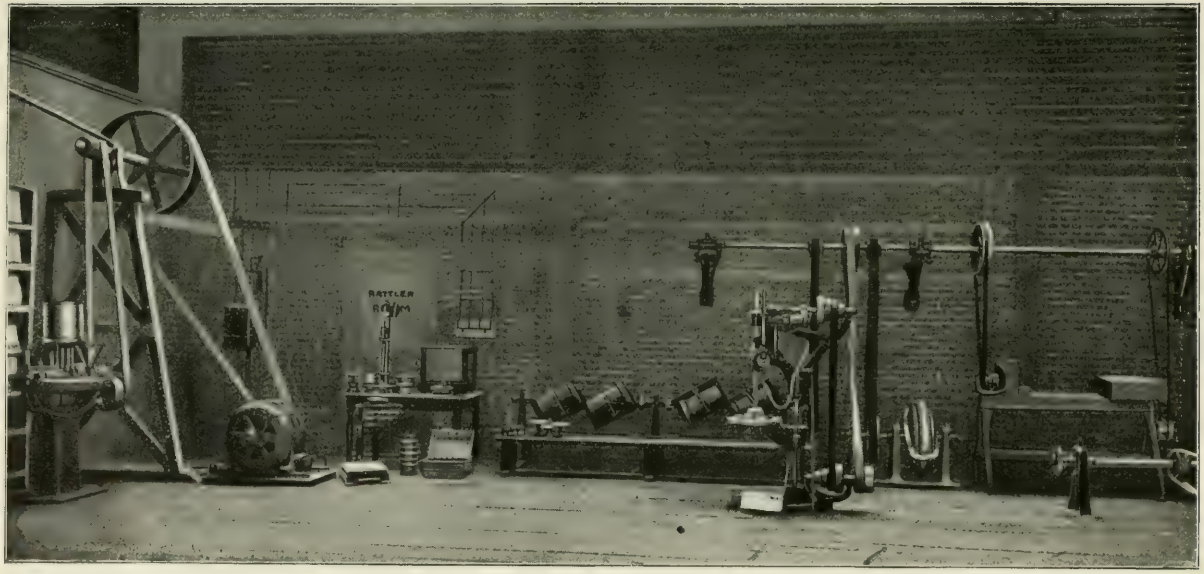


PLATE I.—NORTH SIDE OF ROAD LABORATORY.

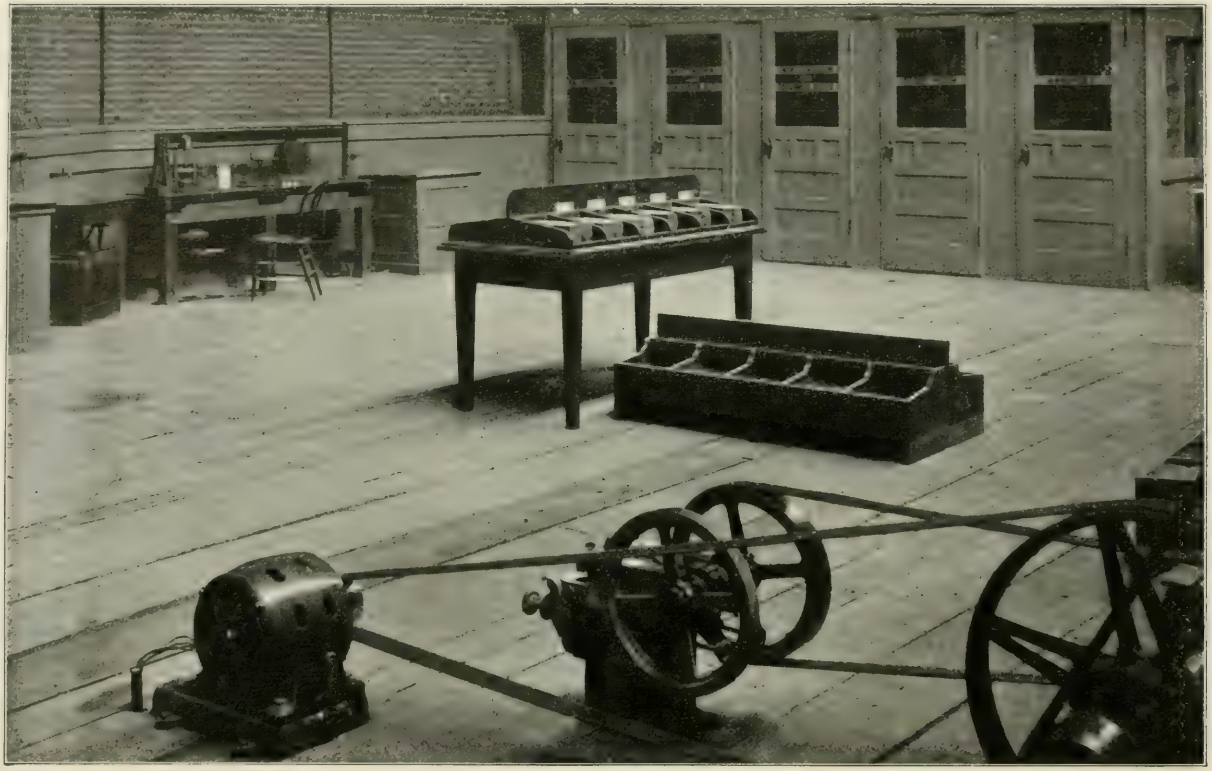


PLATE II.—SOUTHWEST CORNER OF ROAD LABORATORY.

THE ROAD MATERIALS TESTING LABORATORY OF THE UNIVERSITY OF ILLINOIS.

By L. G. Parker, Instructor in Civil Engineering.

Although the construction of improved roads date back to very ancient times, no scientific study of road construction was made until about the middle of the last century.

The French were the first to make a systematic study of road construction. Beginning in 1865 they studied very carefully stone roads to determine the wearing value of different kinds of stone, the relation between the wear and the amount of traffic, the effect of the weather, and the effect of various foundations on different soils. These These observations were made on the material in the road, and were of great value in choosing stone for subsequent road construction. Necessarily the observations required considerable time and were very expensive. Some preliminary laboratory tests were made along with the field observations, and the comparison of the two proved the value of the former, the laboratory tests, requiring shorter time and smaller expense to determine certain road building qualities of the stone. The chief advantage of the laboratory tests was that they made it possible to determine beforehand some of the road-building qualities of a stone.

In 1878 the French Commission of National Roads established a road laboratory in which mechanical tests of road material were made with machines designed especially for that purpose. These machines were on exhibition during that year at the Paris Exposition.

Tests of road materials were first made in this country by the Massachusetts Highway Commission when it established its road laboratory in 1893. Since then laboratories have been established by the Maryland Geological Survey, by the United States Department of Agriculture, and also by several universities throughout the United States.

The Road Materials Testing Laboratory of the University of Illinois is a part of the Engineering Experiment Station which was established December 8, 1903, by an act of the Board of Trustees.

Although the testing machines had been on hand for some time, for lack of a room they were not set up until January, 1906. The machines were first set up in a basement room of the Electrical Building but were moved in September, 1906, to the north bay of the Steam Laboratory. It was not until December, 1906, however that the Road Laboratory was fully equipped for making the complete mechanical tests of road building materials.

The Road Laboratory was established at the University of Illinois for the purpose of investigating the road building materials of this state and to determine if possible new methods of making tests which will represent more accurately the action which materials undergo when actually used in roads.

The laboratory equipment is about the same as that of the United States Department of Agriculture, and consists of scales and balances, abrasion and impact machines, stone crusher, ball mill, hydraulic press, core drill, polishing disc, and brick rattlers. The power is supplied by one 2H P and one 10-H. P. inducttion motor. The arrangement of the equipment is shown in Plates I. and II.

The road building material upon which tests are made are the various kinds of stone, gravel, and paving brick. Each kind of material requires a separate set of tests.

Tests of Broken Stone.—To judge of the road building qualities of a stone, tests are made to determine its resistance to abrasion, its hardness, its toughness, its cementing qualities, its specific gravity, and its absorbing power.

The dust which wears from the stone used in the construction of broken stone roads has been found to play a very important part in the maintenance of the road on account of the cementing or building power of this dust. The dust holds in place the stones which form the surface of the road and also aid in producing a smooth surface. Except for the cementing power of the stone dust, stone roads would "ravel," that is the material would be easily displaced by traffic. New broken stone roads require the addition of stone screenings to act as the binding material, but after the road has been in use for some time the binding material is supplied by the wear of the stones in the upper surface of the road. Those stones which show very low recementing values make a poor material for a road surface. The cementation test is made for the purpose of determining the recementing values of stone, and although the results

obtained are very variable the test is considered a very important one.

The specific gravity of a stone is determined for the purpose of obtaining its weight per cubic foot. The amount of water absorbed gives some indication of what the action of the weather will be upon the stone, but as a matter of fact this action is usually small in stones which are likely to be used in road construction.

Most of the laboratory tests of road building materials are of an empirical nature, and are of value only in giving comparative results. Whether or not a stone will give good results when used in a road may be determined by comparing the results of its laboratory tests with the same tests on a similar stone whose qualities have been established by actual use in road construction.

The *abrasion test* is made with a Deval machine which consists of a set of two or four cast-iron cylinders 20 cm. in diameter and 34 cm. deep closed at one end and having a tight fitting iron cover at the other. These cylinders are mounted on a bent horizontal shaft in such a way that the axis of the cylinders make angles of 30 degrees with the axis of rotation of the shaft. The machine is shown in the middle background of Plate I, page...

The stone to be tested is broken into sizes as nearly uniform as possible so that the stone will pass through a 2½ inch ring but will not pass through a 1¼ inch ring. These pieces are cleansed and dried, and then about 50 of them weighing 5000 grams are carefully weighed and placed in a cylinder of the abrasion machine. The rotation of the shaft causes the pieces of stone to be thrown from end to end of the cylinder thus causing them to be worn away. The cylinders are caused to rotate for five hours at the rate of 2000 revolutions per hour. At the end of 10,000 revolutions the stone is removed, and all pieces above 1-16 inch diameter are washed, dried, and weighed. This weight subtracted from the original 5000 grams gives the amount of detritus, and the percentage of the detritus represents the per cent of wear of the stone. The French coefficient of wear is also computed, its value being $400 \div W$ where W is the weight in grams of the detritus per 1000 grams of the stone tested. Not many kinds of stone wear more than 20 per cent when tested in the abrasion machine, while the best road building stones do not wear as much as 10 per cent.

The *hardness test* is made with the Dorrey machine which

consists essentially of a cast iron disc about 80 cm. in diameter mounted so as to rotate in a horizontal plane. It is shown in the foreground at the left of Plate I. Clamps are arranged so that two specimens can be held against the grinding disc at distances of 26 cm. from its center. A specimen consists of a cylindrical core of stone 25 mm. in diameter cut by means of a diamond drill. A common drill press fitted with a diamond drill is shown in the center of Plate I. The specimen is weighed and its length determined, and then it is placed in the machine so that one of its ends rests upon the disc and it is weighted in such a way that it has upon it a pressure of 250 grams per square centimeter. The disc is caused to rotate through 1000 revolutions at the rate of 2000 revolutions per hour, and during that time there is fed upon the disc one liter of crushed quartzite rock, screened to a size between one and two millimeters, with enough water to keep the quartzite wet. At the end of the 1000 revolutions the cores are removed from the machine and again weighed and measured. Next the cores are turned other end down in the machine and the above operations are repeated. After the grinding has been completed the average amount of wear per 1000 revolutions is determined for each specimen. This wear in millimeters of length subtracted from 20 gives the coefficient of hardness used at the United States Government Road Laboratory. Good road building stone should not have coefficients of hardness less than 5.

The *toughness test* is made by placing a core of 25 mm. diameter and 25 mm. length under a 2 kg. hammer which is caused to fall from different heights beginning with one centimeter and increasing by one centimeter for each blow until the specimen breaks. The number of blows required to break the specimen represents its toughness. A specimen from a good stone should not break with less than 5 blows.

The *cementation test* is made as follows: The stone to be tested is passed through a crusher and broken into pieces varying in size from one to five millimeters. Five hundred to 1000 grams of this material is then placed in the ball mill (shown to the right of the drill press in Plate I) which consists of a cast-iron shell mounted on a horizontal shaft and having two 20 pound balls in the shell running one behind the other in such a way that the material placed

in the mill is pulverized by the balls. The material is ground in this way during the time that the shell is turned through 5000 revolutions at the rate of 2000 revolutions per hour. After the grinding has been completed the material is removed from the mill and mixed with about 180 cc. of water per 1000 grams of stone dust, for a period of about 10 minutes. The mixture is then placed in a tightly closed jar and allowed to stand 12 hours after which it is moulded into briquettes 25 mm. in diameter and 25 mm. long. These briquettes are made by placing the material in a steel die and compressing it with a plunger which is forced into the die by a hydraulic pressure of 100 kg. per square centimeter. The press used is shown in the background at the left of Plate II page ..... Five briquettes constitute a set and after they have been made they are allowed to dry in the air for 12 hours, and then are placed in an oven heated to 100 degrees Centigrade and dried for 7 hours. The briquettes are then removed from the oven and placed in a desiccator to cool. After they have cooled they are placed under a flat-end plunger of one kilogram weight which receives the impact of a one kilogram hammer having a one centimeter fall. The impact apparatus is shown on the table in Plate I. It has a small electric motor at the top for raising the hammer, and an indicator drum at the bottom upon which an automatic record is made of the blows received by the test piece. The average number of blows required to break the five briquettes represents the cementing power of the stone dust. A cementing value of 10 is considered low, 20 fair, 40 good, and all values above 50 are considered excellent.

In the test as just described the material was ground dry in the ball mill, but the cementation test is also made by adding water to the crushed rock when it is placed in the ball mill. When the ground material is removed from the mill it is immediately made into briquettes which are dried in the air 16 hours and in the oven 7 hours. From this point the briquettes are handled in the same way as the briquettes made from the dry-ground material. Briquettes made from the wet-ground material are often much stronger than those made from the dry-ground material.

The *specific gravity* and *absorption tests* are made by choosing two small specimens weighing from 10 to 15 grams each from the sample of stone, and these specimens are dried and each carefully weighed on a fine balance in air and then are suspended in a beaker

of water and again weighed. From the data thus obtained, two values for the specific gravity and the weight per cubic foot of the stone are found, one being used as a check upon the other. The specimens are allowed to remain in water for 96 hours after which they are again suspended from an arm of the fine balance into the beaker of water and weighed. From the first and last weighing of the specimens in water, the number of pounds of water absorbed per cubic foot is computed.

It is not possible to specify the test requirements for a good road building stone which will answer all purposes since varying volumes and character of traffic and climatic conditions as well as the cost of available material are factors to be considered in the choice of a stone. No broken stone is suitable for roads carrying the heaviest traffic, as city streets, which must have surfaces paved with stone, brick, or wood block or with asphalt. A road which takes heavy highway or suburban traffic requires stone of the highest hardness, toughness, and wearing qualities; on the other hand for country roads of light traffic a comparatively soft stone of medium toughness is required. Wind and rain remove stone dust from the surface of the road so that for the best results that stone should be chosen which will wear sufficiently to supply the deficiency in the amount of stone dust. Rocks which have the higher cementing values require less wear to provide the right quantity of binding material.

Tests of Gravels.—The tests made upon gravels are the determination of its weight per cubic foot, the percentage of voids, the percentages of the different sizes of stone, the amount of clay or other material which can be readily removed by washing, also the determination of the cementation values.

The *specific gravity* and *percentage of voids* of gravel are found in the following manner: Quantities of water and dried gravel are weighed in separate vessels; and then a half-gallon fruit jar, whose water capacity has been accurately determined, is filled with this water and gravel keeping the surface of the water just above the surface of the gravel during the filling process to avoid the lodging of air bubbles in the gravel. The jar is jolted from time to time to cause the gravel particles to settle closely together. The remaining water and gravel in the two vessels subtracted from the original quantities give the amount of each in the jar. The ratio of the

water in the jar to the water capacity of the jar gives the percentage of voids. The ratio of the weight of the gravel in the jar to the water capacity of the jar gives the specific gravity of the gravel, from which its weight per cubic foot can be computed.

The *variation of sizes* of the gravel particles and the amount of *material in suspension* is determined as follows: Enough dry gravel is weighed out and added to the gravel used in the test described above to make 5000 grams. This gravel is then thoroughly washed, dried, and weighed. The loss of weight thus found indicates the amount of suspended matter in the 5000 grams of gravel. The washed material is screened with sieves having openings of the following diameters: 2, 1, 1-2, 1-4, 1-16, and 1-32 inches, and also with a No. 100 sieve. The amount of material retained on each sieve and that passing the 100-mesh sieve is then determined and the several percentages computed.

The *cementation tests* of gravel are made in the same way as those for stone, the material being used as it came from the pit.

Gravel in a road is held in place either by the binding action of some foreign substance or by the dust made by the wear of the gravel particles. The binding action is also assisted by having the material so graduated in size that the voids in the gravel are a minimum. The binding material in a gravel may consist of clay, loam, sand, stone dust, iron oxide, etc. Clay is by far the most common binding material found in gravel, and a cementation test on clay alone shows it to have unusually high cementing qualities; but it does not make a good binding material because its binding qualities depend too much on the condition of the weather. Loam as a binding material has the same defects as clay. Finely divided silica sometimes found in gravels makes a very good cementing material. Iron oxide is often found as a coating on the pebbles, and has a very high cementing action. Clean flinty gravels do not make good roads unless some material is used to act as a binder; but ferruginous and other gravels containing ingredients which when ground to a powder under the action of traffic have high cementing power, make excellent roads.

Tests of Paving Brick.—The paving brick tests universally used are those prescribed by the National Brick Makers' Association commonly known as rattler and absorption tests. The rattler test is considered of much greater importance than the absorption test,

and is of value in determining the wearing value of brick. The absorption test is made chiefly for the purpose of determining the uniformity of any make of brick.

The Laboratory is equipped with both the standard and the Talbot-Jones rattlers. A few tests have been made with the Talbot-Jones rattler, but up to the present time the results obtained have not been of sufficient value to give this rattler a place as a recognized apparatus for making brick tests. However it has some features which recommend it, one of these being the fact that the bricks receive the abrasive action more nearly as they do in an actual pavement than is true of the bricks tested in the standard rattler.

The standard rattler consists of a cast-steel barrel arrangement having compartments clear of obstructions 28 inches in diameter and 20 inches long. These compartments have plane ends, and sides composed of 14 flat cast-steel bars with space left between them to permit the brick dust to escape.

The *rattler test* is made by placing a charge of brick and iron shot in a compartment of the rattler, and then causing the barrel of the rattler to revolve 1800 times at the rate of 28 to 30 times per minute. The charge of brick consists of enough paving brick to make about 1000 cubic inches of material (about 12 paving bricks or 9 paving blocks) which are carefully dried and weighed before being placed in the rattler. The charge of cast iron consists of 225 pounds of $1\frac{1}{2}$ inch cast-iron cubes weighing about $\frac{7}{8}$ pound each, and 75 pounds of $2\frac{1}{2} \times 2\frac{1}{2} \times 4\frac{1}{2}$ inch cast-iron blocks with slightly rounded edges weighing about $7\frac{1}{2}$ pounds each. At the end of the 1800 revolutions the bricks are removed from the rattler and again weighed. The loss of weight calculated in per cent gives the value which is used in determining the wearing value of the brick. As a check on the work the tests are always duplicated. It is usually specified that paving brick should not show more than 18 per cent of wear.

The *absorption test* is made by choosing two bricks which have been used in making the rattler test and carefully weighing them. They are then placed in water and allowed to remain for 48 hours, after which they are removed and wiped dry and again weighed. The percentage of increase in weight is determined, and the amount of absorption is thus expressed in per cent.

THE FLOW OF STEAM THROUGH NOZZLES.

By Franklin W. Marquis '05, Mechanical Engineering.

In the application of the flow of steam through a nozzle to steam-turbine work, the point at which the velocity of the steam is required is generally very near the end of the nozzle. In looking over the reports of other experiments in this same line it was noticed that in some cases in order to get the velocity it was necessary to estimate the density of the steam at the point of efflux. This estimation depended upon temperature measurements, which were likely to be inaccurate, and seemed to be a weak point in the experiments. Moreover, the velocity found by this method was merely a figure in feet per second, from which the mass of steam discharged could be calculated, when the area of the orifice and the density of the steam were known. Therefore, in the present experiments it seemed desirable to measure the velocity as directly as possible, and to avoid estimating the density of the steam at the point of efflux. It was therefore necessary to measure both the mass discharged and some other quantity involving the velocity. For this second quantity the impulse of the escaping jet was chosen.

Let V = the velocity of the steam, in feet per second.
W = the impulse in pounds weight.
M = the weight of steam discharged per second, in pounds.
and g = the acceleration due to gravity,
= 32.16 feet per second per second.

Then, since the impulse of a jet of any kind is equal to the product of the mass flowing per second and the velocity of flow,

$$W = \frac{M V}{g}$$

$$\text{or } V = \frac{W g}{M} \qquad (1)$$

The above formula was used in all cases in determining the

Editor's Note.—Abstract of thesis on experimental determination of the velocity of flow of steam through nozzles.

velocity of the jet. It is to be noted that this formula gives the velocity at the definite point at which the impulse is measured. Thus, if the steam is not fully expanded in the nozzle, it will continue to expand after leaving the nozzle, and will change in impulse and velocity. However, the velocity at any point outside the nozzle may be obtained by measuring the impulse at that point.

At first an attempt was made to measure the reaction of the jet, instead of the impulse, the supposition being that the two would be the same. However, after some preliminary experiments this method was abandoned, and a method of measuring the impulse was substituted.

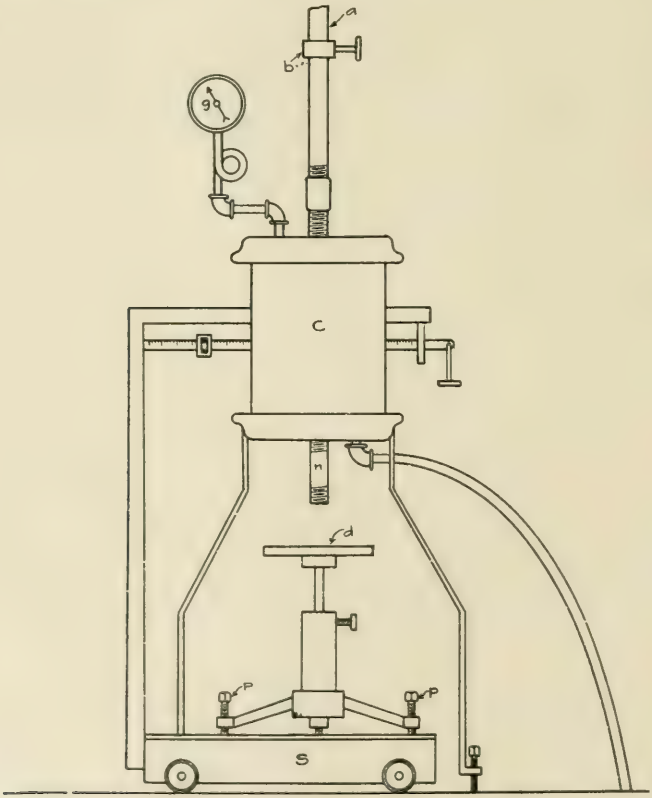


FIG. 1.—DIAGRAM SHOWING ARRANGEMENT OF APPARATUS FOR MEASURING THE IMPULSE OF THE JET.

Steam for the following experiments was furnished by a Babcock and Wilcox water tube boiler, which generally carried about 125 pounds pressure.

Fig. 1 shows the arrangement of the apparatus used in determining the impulse of the jet. It consisted of a receiver, c, into which steam was admitted by means of the one inch pipe, a. The nozzle, n, was screwed into the lower end of c. The steam was discharged from c through nozzle n, directly against the impulse plate d, which was supported on the scales s, the impulse thus being measured directly. The pressure of steam in c was regulated by means of the gate valve b, the gage g, showing just what this pressure was. The impulse plate d, could be set at any desired distance from the end of the nozzle. It was set perpendicular to the axis of the nozzle by means of the leveling screws, P. The steam inlet pipe, a, extended some distance into the receiver c, and had a cap on its lower end. A number of ¼" holes were drilled in it at different places within c. This prevented the steam from rushing directly from the pipe into the nozzle, and tended to equalize the steam pressure in all parts of c. The nozzles were threaded and screwed in as shown in the fig., care being taken to have them extend at least ¼" up into the receiver. A ⅛" pipe, through which steam flowed continually during each test, led away from the bottom of the receiver. This served to drain the water which collected there, and to keep the steam, which flowed through the nozzle, dry. The steam gage used was graduated to read to 5 pounds, and was carefully calibrated before being used. The scales were graduated to read to .02 pounds, and were also carefully calibrated.

The method followed in each experiment was as follows: The impulse plate was first set perpendicular to the axis of the nozzle, and at the desired distance from it. The scales were then carefully balanced. The steam was then turned on, and the pressure in the receiver allowed to reach the maximum desired, which was, in most cases, 120 pounds. It was allowed to remain at this pressure for several minutes, until the apparatus was thoroughly warmed up, after which the scales were balanced and the reading taken. The valve b, was then closed just enough to cause the steam pressure in the receiver to fall ten pounds. As soon as the pressure became steady, another reading was taken. Thus a read-

ing was taken for each ten pounds from the maximum to the minimum desired. The pressure was always decreased from one reading to the next, as this tended to keep the steam dry. Some trouble was experienced from water collecting on the scales, and it was found necessary to keep this carefully wiped off. In other respects the apparatus worked satisfactorily, and the results obtained are supposed to be fairly accurate.

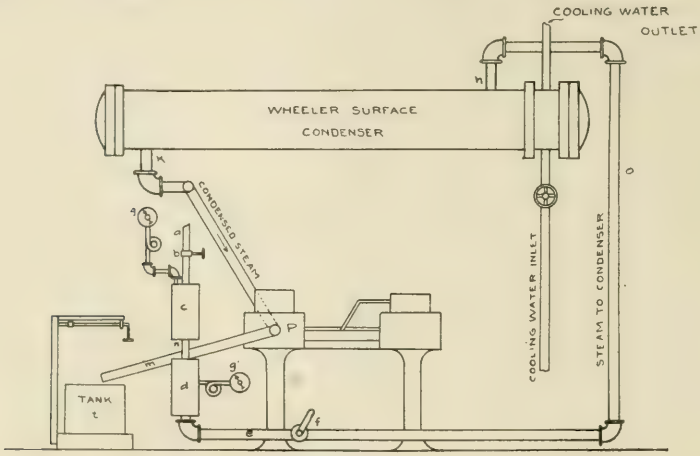


Fig. 2.—Diagram Showing Arrangement of Apparatus for Measuring the Mass of Steam Discharged.

Fig. 2 shows the arrangement of the apparatus used for determining the mass of steam discharged. The same receiver, c, was used as in determining the impulse of the jet. The hollow cylindrical receiver, d, was screwed on the lower end of the nozzle. A compound gage, g′, was connected to d, as shown in the figure, so as to give the pressure in d. From the lower end of d, a 2″ pipe led to a Wheeler surface condenser. In this 2″ pipe, near the receiver d, was a throttle valve, f. At k, the steam, now condensed, left the condenser, and was forced by the wet air pump into the tank t, which rested on the same scales that had been used in determining the impulse of the steam.

The method used was as follows: The condenser pump was first started, and the throttle valve, f, opened wide. The valve, b, was then opened, admitting steam to c, up to the maximum pres-

sure used. The steam was now discharging from c into d, against some pressure less than atmospheric. The throttle valve, f, was then gradually closed until the compound gage, g', read just 0. The steam was then being discharged against atmospheric pressure. It was allowed to run for several minutes until a state of stability was reached. Meanwhile the scales, on which the empty tank, t, rested, were balanced. Then at some definite time, which was carefully noted, the pipe, m, which up till this time had been discharging to waste, was turned so that it discharged into tank t. Both pressures in c and d, were then kept constant until an interval of 15 minutes had passed, when the pipe m was again turned so that it discharged to waste. The water which had collected in t was then weighed. This weight was divided by the time in seconds, the result being the weight of steam discharged per second. This process was repeated for a steam pressure corresponding to the next ten pounds lower, and so on to the minimum pressure desired.

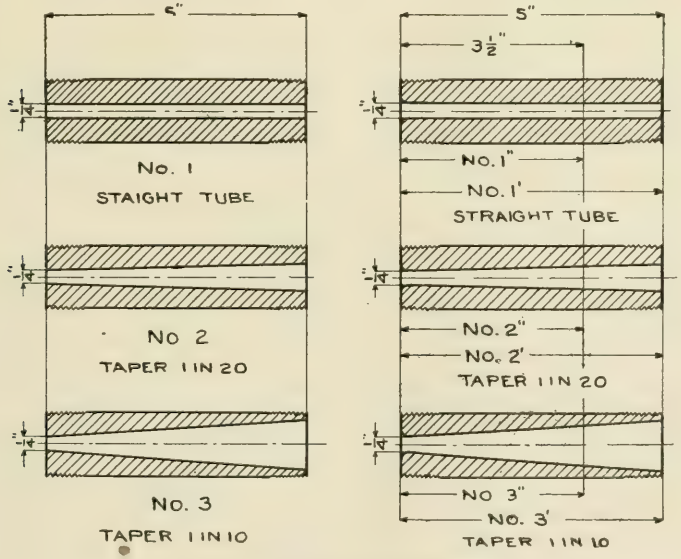


Fig. 3.—Nozzles Tested.

It was found necessary to wait some little time after the steam was first turned on in order to be sure that a condition of stability had been reached. Otherwise the weight discharged was

entirely too large. This was accounted for by the supposition that, when the steam was first turned on, or when the pressure was raised, water which had collected in the pipe e, and the upright o, see fig. 2, was carried over into the condenser, and on into the tank t, thus giving a larger weight than had actually passed through the nozzle. When precautions were taken against this error, the results seemed to be fairly uniform.

Before any tests were made, a careful leakage test was run on the condenser, to make sure that none of the cooling water was finding its way into tank t.

The nozzles tested, see Fig 3, were made of brass, and were carefully prepared to exact dimensions.

No. 1 is simply a straight tube ¼" in diameter and 5" long, with a sharp inner edge.

No. 1′ is the same as No. 1, with the inner edge rounded.

No. 1″ is the same as No. 1′, but is only 3½" long.

No 2 has a taper of 1 in 20, is 5" long, ¼" in diameter at the small end, and has a sharp inner edge.

No. 2′ is the same as No. 2, with the inner edge rounded.

No 2″ is the same as No. 2′, but only 3½" long.

No. 3 has a taper of 1 in 10, is 5" long, ¼" in diameter at the small end, and has a sharp inner edge.

No. 3′ is the same as No. 3, with the inner edge rounded.

No. 3″ is the same as No. 3′, but is only 3½" long.

Results and Conclusions.

The more important results obtained will be found expressed graphically in figures 4-9. Two velocities were calculated for each nozzle as follows: (1) The velocity near the end of the nozzle, generally ¼" from it, where the impluse was a minimum, and (2) the velocity at the point where it was a maximum. This was at 2½" from the end of the nozzle in most cases, but with nozzles No. 1′, No. 3 and No. 3′ it was at 2", and with No. 2′ it was at 1" from the end of the nozzle. Thus, practically, the minimum and maximum velocities of the steam, after it leaves the end of the nozzle, are recorded in each case. Curves are given for each nozzle, having the steam pressure in pounds per square inch above atmosphere as abscissal and (1) the impulse in pounds, (2) the velocity in feet per second, as ordinates.

An examination of the steam pressure impulse curves, see figures 4, 5 and 6, will show the following points. Of nozzles No. 1, No. 2 and No. 3, with the square inner edge, No. 1 gave the greatest impulse, No. 2 the next and No. 3 the least. However, it will be noticed that curves 2 and 3 have a greater slope than 1, so that if they were continued they would cross 1. This seems to indicate that if much higher pressures were used the nozzles No. 2 and No. 3 would give a greater impulse than No. 1.

When the inner edges were rounded, thus admitting more steam, the impulse with nozzle No. 1′ was greater than the others only at the lower pressures, see figure 5. At the higher pressures, nozzle No. 2′ gave the greatest and No. 1′ the elast. This same thing is shown in a more marked degree by the curves in figure 6,

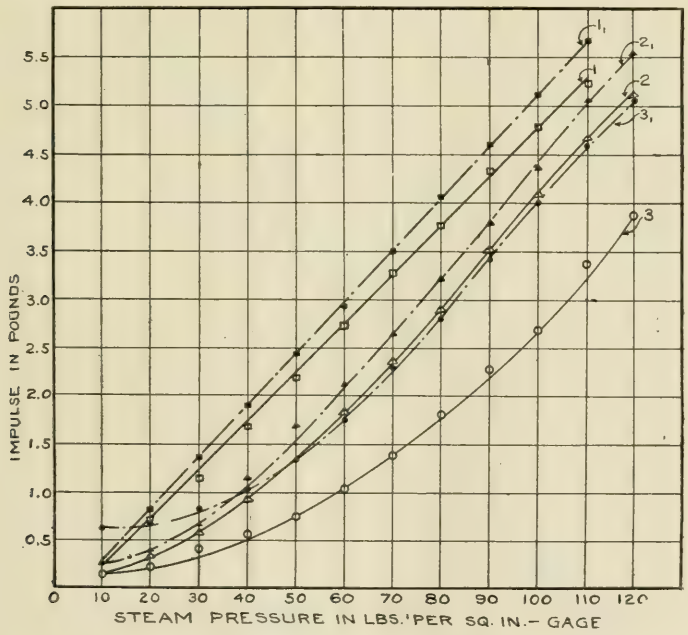


FIG. 4.

1—Impulse measured at $\frac{13}{32}$″ from the end of nozzle No. 1
1_1— " " " $2\frac{1}{2}$″ " " " " " " " 1
2 — " " " $\frac{1}{4}$″ " " " " " " " 2
2_1— " " " $2\frac{1}{2}$″ " " " " " " " 2
3 — " " " $\frac{1}{4}$″ " " " " " " " 3
3_1— " " " 2″ " " " " " " " 3

which show the effect of shortening the nozzles. This all seems to show that of the nozzles with the square inner edge, both No. 2 and No. 3 are too long, and have too much taper, thus allowing the steam to expand to the lower pressure somewhere back in the nozzle, instead of just at the mouth, as it should. When the inner edges were rounded, more steam was discharged, but evidently nozzle No. 3 still had too much taper, even at the highest pressures reached.

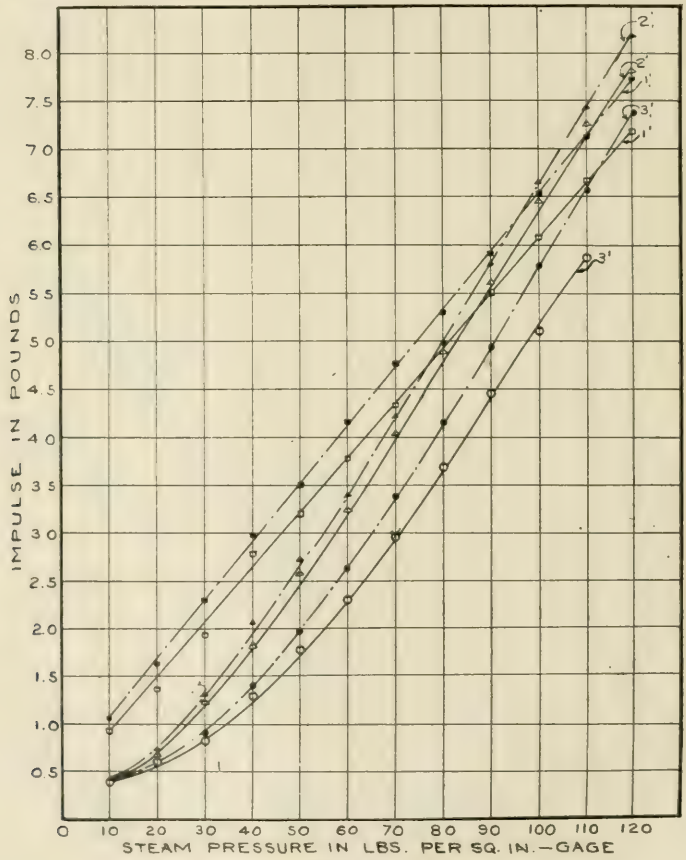


FIG. 5.

1′—Impulse measured at ¼″ from end of nozzle No. 1′
1′—" " " 2″ " " " " " 1′
2′—" " " ¼″ " " " " " 2′
2′—" " " 1″ " " " " " 2′
3′—" " " ¼″ " " " " " 3′
3′—" " " 2″ " " " " " 3′

The greatest discharge was given in each case by the nozzle with the larger taper (1 in 10), although there was very little differenec between that and the one with the taper 1 in 20. The straight tube, however, plainly gave the least discharge in every case, except at some of the lower pressures.

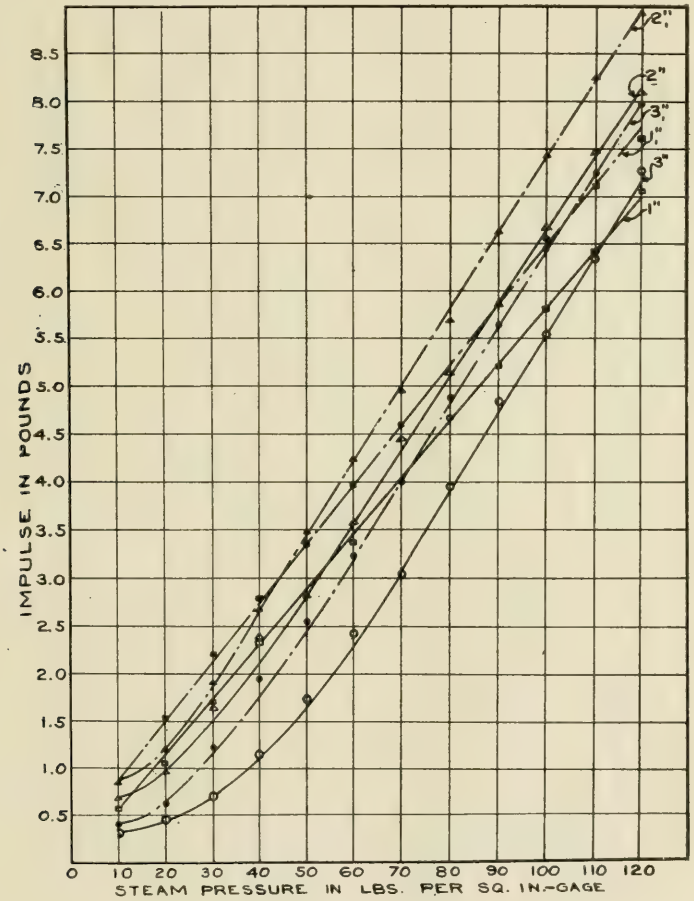


FIG. 6.

1″—Impulse measured at ¼″ from end of nozzle No. 1″
1$_1$″— " " " 2½″ " " " " " 1″
2 ″— " " " ¼″ " " " " " 2″
2$_1$″— " " " 2½″ " " " " " 2″
3 ″— " " " ¼″ " " " " " 3″
3$_1$″— " " " 2½″ " " " " " 3″

An examination of some of the steam pressure-velocity curves (figures 7, 8 and 9) will show that the highest velocity was given by the straight tube in every case except in the case of the shorter nozzles, when the nozzle with the taper 1 in 20 gave

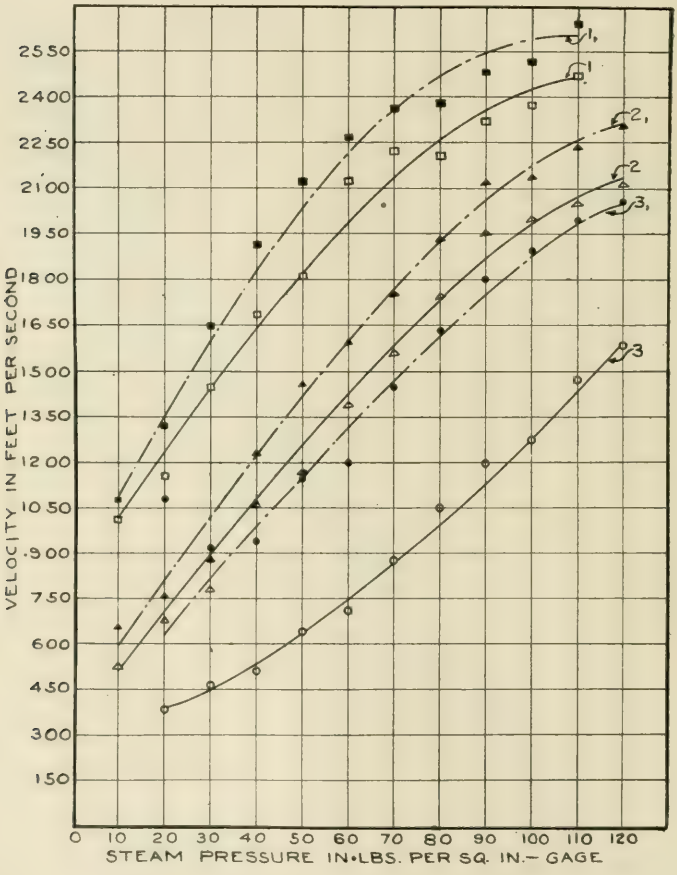


FIG. 7.

1 —	Velocity at	$\frac{13}{32}$"	from end of nozzle	No. 1
1_1 —	"	"	$2\frac{1}{2}$"	"	"	"	"	"	1
2 —	"	"	$\frac{1}{4}$"	"	"	"	"	"	2
2_1 —	"	"	$2\frac{1}{2}$"	"	"	"	"	"	2
3 —	"	"	$\frac{1}{4}$"	"	"	"	"	"	3
3_1 —	"		2"	"	"	"	"	"	3

the highest velocity. One rather interesting point which is shown plainly in figure 9, is that with the straight tube the velocity decreases very slowly as the steam pressure is lowered, while with the taper nozzles it decreases much more rapidly.

Thus these experiments show that for steam pressures above 90 lbs. gage the nozzle with the taper 1 in 20 and 3½″ long, with

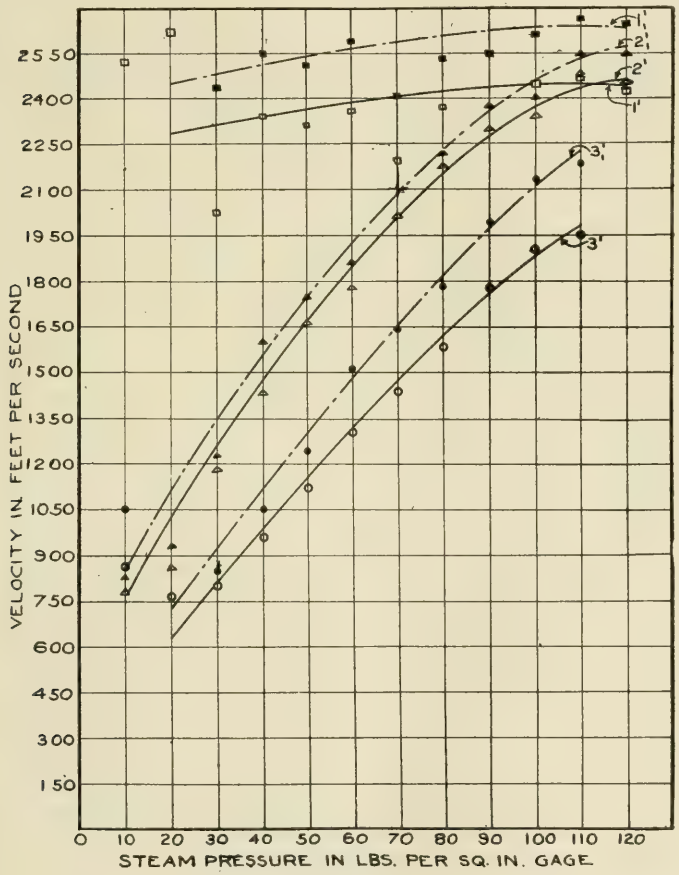


FIG. 8.

1′—	Velocity	at	¼″	from	end	of	nozzle	No.	1′
1_1′—	"	"	2″	"	"	"	"	"	1′
2′—	"	"	¼″	"	"	"	"	"	2′
2_1′—	"	"	1″	"	"	"	"	"	2′
3′—	"	"	¼″	"	"	"	"	"	3′
3_1′—	"	"	2″	"	"	"	"	"	3′

the rounded inner edge, was the best of any tested. For pressures below 90 lbs. a tube of less taper, or even a straight tube, is evidently better.

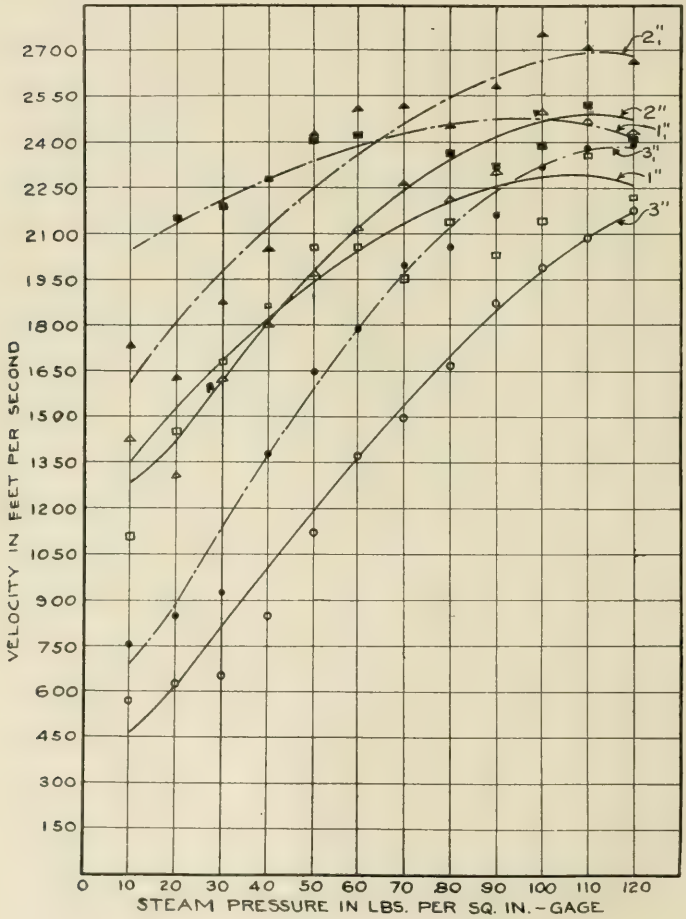


FIG. 9.

1″—Velocity	at	¼″	from	end	of	nozzle	No.	1″
1_1″—	"	"	2½″	"	"	"	"	1″
2″—	"	"	¼″	"	"	"	"	2″
2_1″—	"	"	2½″	"	"	"	"	2″
3″—	"	"	¼″	"	"	"	"	3″
3_1″—	"	"	2½″	"	"	"	"	3″

STRESSES IN CONCRETE SEWER SECTIONS.

By. A. P. Poorman, '07, Civil Engineering.

In recent years, reinforced concrete has come into use more and more as a building material. One reason for this is that the high tensile strength of steel can be combined with the high compressive strength of concrete so as to produce a very efficient building material at low cost. Another reason is that concrete can be easily molded into any shape that may be desired with little loss of materials. For both of these reasons, reinforced concrete is eminently adapted for the construction of sewers, conduits, culverts, pipe and similar structures, especially in the larger sizes. Along this line, practical construction has out-run theoretical determination, for the reinforcing in the sewers and pipes heretofore constructed has, as a rule, been placed without any definite knowledge of the stresses to which the sewers would be subjected.

The Engineering Experiment Station of the University of Illinois, has been conducting some experiments with the object of determining something more definite regarding the position and magnitude of the maximum stresses under various systems of loading. In his thesis entitled, "Stresses in Concrete Pipes Due to External Pressure," Mr. W. A. Slater, M. and S. E., '06, began the investigation, working in conjunction with the Experiment Station in the laboratory tests. This investigation was carried on along two lines, (1) theoretical discussion, and (2) practical tests. In the theoretical determination, three methods of loading were considered, viz.: a concentrated vertical load at the center of the crown; a vertical load uniformly distributed over the horizontal projection; and a combination of a uniform vertical load with a uniform horizontal load. In the determination of moments and stresses, both Pach's formula for moments and stresses and the Cornell method of determining moments were used. The reductions are long and intricate, and hence will be omitted here.

The results of this investigation are very interesting. If we reduce the equations for moment in a ring to the same terms as are used for beams, we get the following results.

For a concentrated load on a ring at the crown, the bending moment at the crown is

$$M = 0.16\ W\ l,$$

where W = load, and $l = 2\ r$ = mean diameter of section.

For a concentrated load at the middle of a simple beam, the bending moment at the middle is

$$M = 0.25\ W\ l,$$

Similarly, for a concentrated load at the middle of a fixed beam,

$$M = 0.125\ W\ l.$$

It is seen from this that the maximum moment in a ring is nearly a mean between that in a simple beam and that in a restrained beam. This is about as might be expected, as may be shown in another way. The distance between the points of inflection of a beam is the length which acts as a simple beam. In the case of the simple beam, this is the distance between supports. In a fixed beam, it is one-half the distance between supports, since the points of inflection are at the quarter points. This makes the moment just half that in a simple beam of the same length. In a ring, the points of inflection are at or near the 45° points, as will be explained later. Considering them to be at the 45° points, we have for the effective horizontal length between points of inflection 0.707 *l*. If the moments varied according to these effective lengths, we would have 0.25 W *l*, 0.176 W *l* and 0.125 W *l* or the moments respectively in a simple beam, a ring, and a fixed beam.

With a uniform load over the horizontal projection, we find the moment at the crown of the ring to be

$$M = 0.0625\ W\ l.$$

For a simple beam, uniformly loaded, the moment at the centre is

$$M = 0.125\ W\ l.$$

For a fixed beam, uniformly loaded, the moment at the centre is

$$M = 0.083\ W\ l.$$

This, also, is as would naturally be expected, for if the vertical forces acting upon the ring are resolved into their normal and tangential components, we find that much of the force produces no moment.

In the case of a uniform horizontal load in combination with

a uniform vertical load, the general formula derived by Mr. Slater reduces to

$$M = 0.25\ (p - h)\ r^2\ \frac{H - 1}{H + 1}$$

where p and h are respectively the vertical and horizontal unit forces or pressures, and H is a function of the ratio of the thickness of section to the mean diameter. For any given pipe H is a constant, and for any ordinary sizes of sewer or culvert pipe, it is so small that it may usually be neglected.

This formula may also be written

$$M = 0.25\ p\ r^2\ (1 - \frac{h}{p})\ \frac{H - 1}{H + 1}$$

It will be seen that this formula reduces to $M = 0$, when $p = h$, or when the horizontal forces are equal in intensity to the vertical forces. This is correct, for from the geometry of the figure, the resultant of any two forces would pass through the centre, and would be equal to the resultant of any other two forces. This is the same as assuming an equal pressure normal to the circumference at all points, which gives zero bending moment at all points.

If h is taken at a representative value of 0.4 p and $\frac{H - 1}{H + 1}$ is considered as equal to —1, since H is very small, we get

$$M = -0.25 \times 0.6\ p\ r^2.$$

Reducing to the same terms as above, and changing sign, since absolute value is all that is desired, we get

$$M = 0.0375\ W\ l$$

which is 0.6 of the value when vertical forces alone are considered.

In all of these cases, except that of uniform normal pressure the moment changes sign at points about 45° from the crown, and again at about 45° from the base, passing through zero at these points. If we consider H = 0, as stated above, these points are exactly at the 45° points, as may be seen from the following. The general equation of moment at any section may be written

$$M = p\ r^2\ (\frac{\sin^2 \Phi}{2} - 0.25)$$

where Φ is the angle with the horizontal. With values of Φ less

than 45° M is negative; with $\Phi = 45°$, M is zero; and with Φ greater than 45°, M is positive.

From the foregoing discussion it is evident that no reinforcing is required if the pressure is normal at all points, except to give strength for handling. In all other conditions, the reinforcing should be placed near the inner surface at the top and bottom, and near the outer surface at the sides, which makes the steel in the form of an ellipse. In order to obtain the same result and also in order to facilitate the removal of the forms, the C. B. & Q R. R. Co. have adopted the plan of separating the upper and the lower semi-circles of the forms by an amount equal to the thickness of the section, which makes this portion straight. The reinforcing rods are then placed in the form of true circles, and consequently are near the tension surfaces of the section.

If the section is large, say eight or ten feet in diameter, a material saving in steel can be effected by using only short pieces of reinforcing, extending each way from the line of maximum moment only far enough to give the bond necessary to develop the full tensile strength.

In the practical test of these theoretical determinations, Mr. Slater used plain concrete sections and a concentrated load, in order to have as many of the conditions fully known as possible. He used only four sizes of test pieces, and but two specimens of each size.

Besides these regular test specimens, two pieces of commercial concrete sewer pipe, 15 inches in diameter, and 1⅞ inches thick, were tested. These had longitudinal reinforcing to help them act as beams if necessary, and this was held together by light lateral reinforcing. The modulus of rupture and the compressive strength of these pieces were unknown, so the test was of little value in aiding the theoretical study of the subject.

With each specimen, compression cubes and beams were made, and from these the modulus of rupture and the compressive strength were figured. Using these values, the load at which failure should occur was computed for each of the eight sections. The load as computed was higher than the actual breaking load, except in the case of one section. The difficulty of getting the section an accurate circle and also of properly tamping the concrete in the molds would probably account for this difference.

By theoretical determination, the tensile stress in the inner fiber at the crown due to a concentrated load should be about 186% of that in the outer fiber at the end of the horizontal diameter. According to this the first failure should occur either at the top or at the bottom. Since the weight of the section itself increases the stress slightly at the bottom this should be the point of initial failure. The tests proved the correctness of this determination, for in the 9 cases noticed, 2 failed at the top, 3 at the bottom, and 4 simultaneously at top and bottom.

In further development of this line of research, the Engineering Experiment Station has begun a series of unique tests upon full sized commercial sections of culvert pipe for railroad embankment, both reinforced concrete and cast iron. Four railroads, the C. B. & Q., the A. T. & S. F., the C. M. & St. P., and the I. C. are uniting in contributing material for these tests. One section 8 feet long, 48 inches inside diameter and 4 inches thick has already been tested. Another the same size, and two 4-ft. sections are on hand ready to be tested. In order to approximate nearly the conditions which occur in actual service, the pipe was imbedded in sand in a box built of heavy timbers. The load was applied uniformly over the horizontal projection by means of a saddle and four hydraulic jacks, each capable of exerting 200,000 pounds pressure. In the specimen tested, failure was due to diagonal tension in the concrete. The load carried was 268,000 pounds, or about 8,000 pounds per square foot of horizontal projection.

The cast iron culvert pipes to be tested are 36 and 48 inches in diameter and 12 feet long. Since the compressive strength and the modulus of rupture of cast iron are well determined, and since it is homogeneous throughout, a more accurate determination of the moment developed should be possible.

Mr. H. B. Bushnell, Mr. J. Cermak and the writer have undertaken a series of tests upon sections similar to the larger ones used by Mr. Slater. They are all to be 48 inches inside diameter and 24 inches long. Six plain concrete sections with 6 inch walls are almost ready for testing. Thirty-three other sections with 4-inch walls and with ¼-inch reinforming bars spaced 3 inches apart, have been made and will be used in determining as far as possible the value of reinforcing.

CONSIDERATION OF THE EFFECT OF FRICTION ON STEAM TURBINE BLADES.

By J. F. Ervin, '07, Mechanical Engineering.

The consideration of indicator diagrams as characteristics of the thermodynamical qualities of reciprocating engines is the common practice with which we are familiar. The steam turbine gives us an entirely different state of affairs. It substitutes for the intermittant closed process of the reciprocating engine, a continuous open process in which steam is admitted at a definite initial pressure and taken away from turbine at a smaller exhaust pressure. For a multiple expansion turbine or one that is composed of part-processes in the individual pressure stages of the turbine, steam issues from a nozzle at some velocity, depending upon the difference between the initial and final pressures and the form of the nozzle. The impulse of this issuing jet gives to the turbine blades, upon which it impinges, a velocity that depends upon the angle of entrance and absolute velocity of jet. Since the heat energy of the fluid is partially transformed into kinetic energy by expansion in the nozzle it is necessary for maximum efficiency, to transform as much of this kinetic energy into work upon the turbine blades as possible, which is the same thing as making the absolute velocity of jet as small as possible when it leaves the last set of rotating blades. Neglecting the losses due to friction, eddies and leakage the energy given up to the blades is proportional to the differences of the squares of the entering and exit velocities. The angles of the blades other than at the points of entrance and exit are immaterial except that blades should be formed with a smooth gradual curve to make the friction and eddy losses small. The tangent to the curve of blade at point of entrance of jet should be parallel to the relative velocity of jet so as to allow jet to enter the blade without shock.

Consider the case shown in Fig. 1 in which we have one pressure and two velocity stages, steam issuing from a nozzle at a velocity V, making an angle a with the horizontal or direction of blade velocity u, and a coefficient of friction of .2 upon both the rotating and guide blades of turbine.

For a condition of maximum efficiency the absolute velocity V_2' of exit jet must be as small as possible. To satisfy this condition

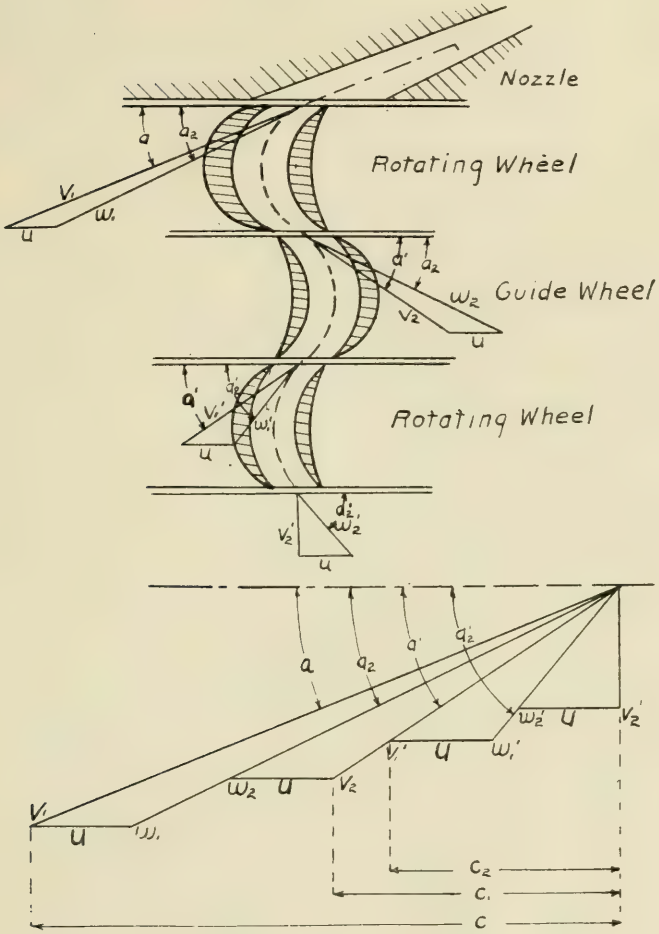


FIG. 1.—VELOCITY DIAGRAM FOR A TWO VELOCITY STAGE TURBINE.

the velocity u of the blades must have such a value as to make V_2' perpendicular to the direction of blade velocity u. For frictionless case a value of u to obtain this condition would be $\frac{V_1 \cos a}{2\ n}$ where n is the number of rotating blades in one pressure stage. When friction is considered the value of u is something smaller than the ideal value and the following empirical formula gives approximate values for u when $n = 2 \times 3$.

$$u = \frac{2V_1 \cos\alpha - (2n-1) f V_1 \cos\alpha + (f-.2) V_1 \cos\alpha + .1n(n-3)(V_1 \cos\alpha) f}{4n - (2n-1) f}$$

$$= \frac{[2 + (.1n^2 - 2.13n + 1) f] V_1 \cos\alpha}{4n - (2n-1) f}$$

f = coef. of friction on blades
V_1 = velocity of jet ft. per sec.
n = sets of rotating blades
u = velocity of blades in ft. per sec.

The velocity diagram shown in Fig. 1 was constructed, using values of u determined by application of above formula after being corrected by trial on velocity diagram.

The jet from the nozzle with a velocity V_1 strikes the moving vanes and enters the blades with a relative velocity W_1; but in passing through the first set of blades .2 of W_1 is lost, which leaves W_2 as the remaining velocity. Then considering the entrance and exit angles of the rotating and guide wheels equal the jet issues from the first set of rotating blades with a relative velocity W_2 making an angle a_2 with the blade velocity vector and enters the guide wheel blades at an absolute velocity V_2 and angle a′ and leaves with an absolute velocity V_1' equal to .8 V_2 and an agle a′. The jet then enters second set of rotating blades with relative velocity W_1' and leaves with a relative W_2' equal to .8 W_1', making an angle a_2', or with an absolute velocity V_2', making an angle of 90° with direction of blade velocity.

In determination of efficiency under these conditions let

$$Wo = \text{energy of jet} = \frac{V_1^2}{2g}$$

f = coef. of friction considered
P = total peripheral component or force upon blades
M = mass of steam flowing per sec.
a and c_1 = peripheral components of velocity at entrance to and exit from first rotating wheel

c_2 = peripheral components of entrance to end exit from second rotating wheel

$\therefore P = M\ (c + c_1 + c_2 + o)$

since c a c_1 are opposite in direction

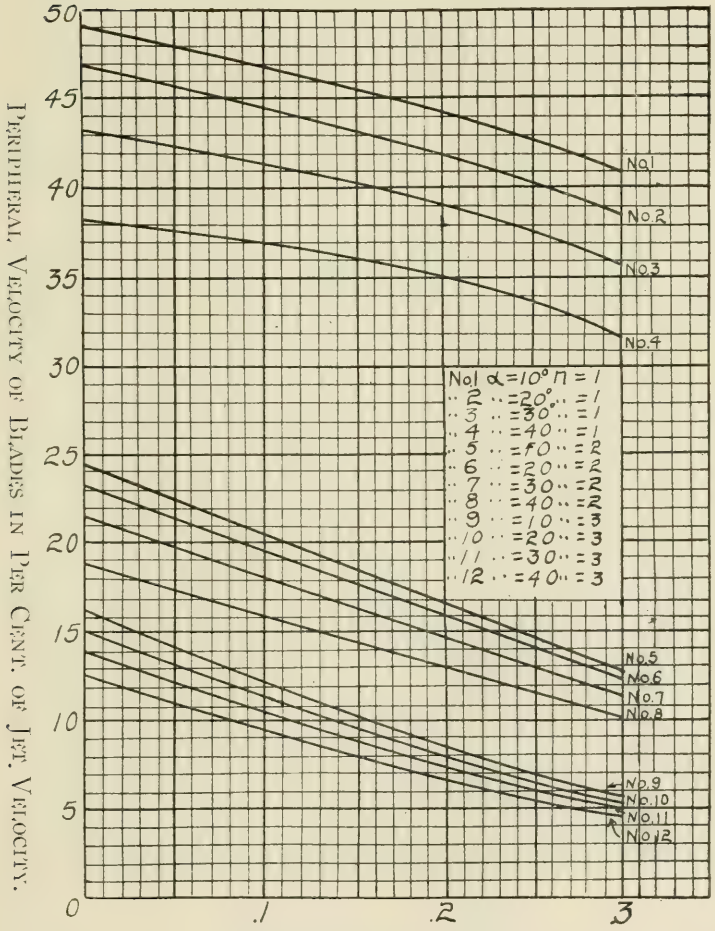
W_1 = work per sec. = Pu

$\therefore W_1 = Pu = M\ (c + c_1 + c_2 + o)\ u$

Considering one pound of steam $M = \frac{1}{g}$

$$\therefore Pu = \frac{(c + c_1 + c_2 + o)\ u}{g} = W_1$$

$$\text{Eff.} = \frac{W_1}{W_o} = \frac{2g\,Pu}{V_1^2} = \frac{2u\ (c + c_1 + c_2 + o)}{V_1^2}$$



PERIPHERAL VELOCITY OF BLADES IN PER CENT. OF JET VELOCITY.

COEFFICIENT OF FRICTION.

PLATE I.—CURVES SHOWING CONDITIONS FOR MAXIMUM EFFICIENCY.

Plate I shows the effect of friction upon the peripheral velocity of the turbine for condition of maximum efficiency described above. The ordinates represent the blade velocity as per cent. of velocity of jet issuing from nozzle and abscissae, the coefficients of friction considered. The different curves shown in the plate were drawn from

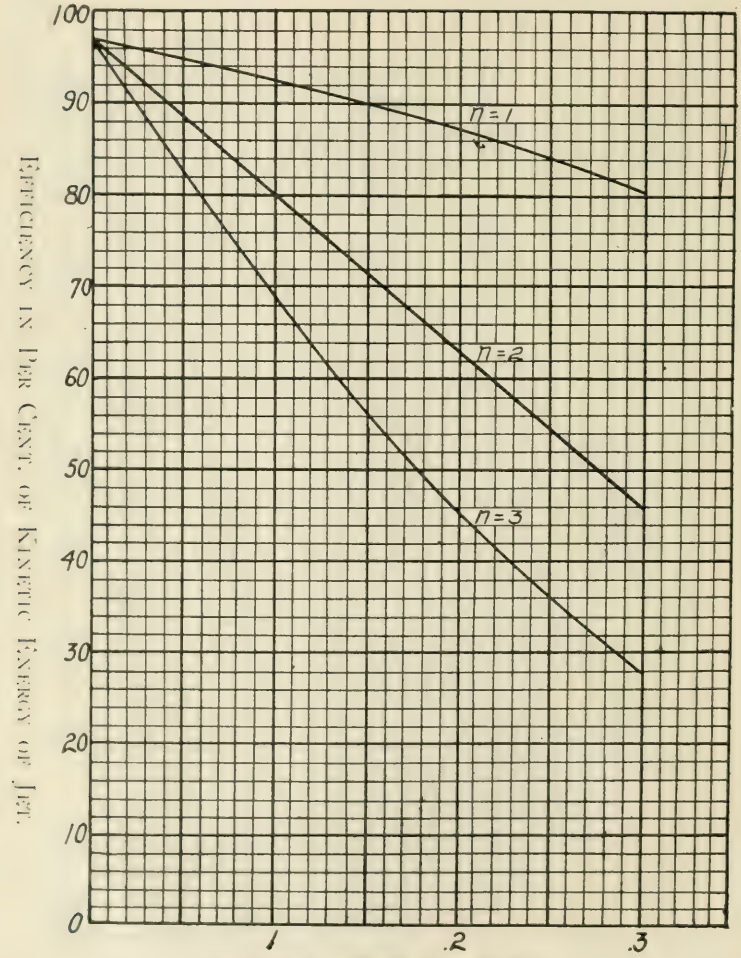


Plate II.—Curves showing efficiency of a turbine with different coefficients of friction when angle of the nozzle is 10°.

the graphical solution of problems similar to that described in Fig 1, considering angles of nozzle 10°, 20°, 30° and 40°, and sets of rotating blades (n) in one pressure stage from 1 to 3 and coefficients of friction from 0 to 3.

Plate II, III, IV and V show the effect of the different angles

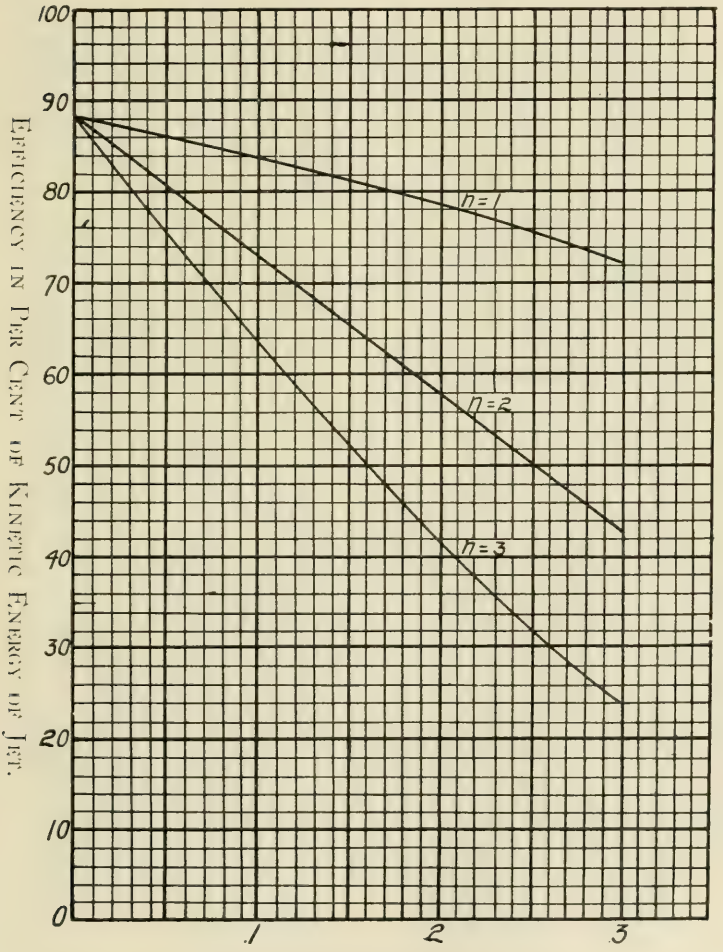


Plate III.—Curves showing efficiency of a turbine with different coefficients of friction when the angles of the nozzle is 20°.

of entrance and friction upon the blades in terms of the efficiency of the jet. The ordinates represent the efficiency of the combination in per cent. of jet energy and the abscissae the coefficients of friction considered. The results for these curves were calculated from the graphical solution of problems as described in Fig 1.

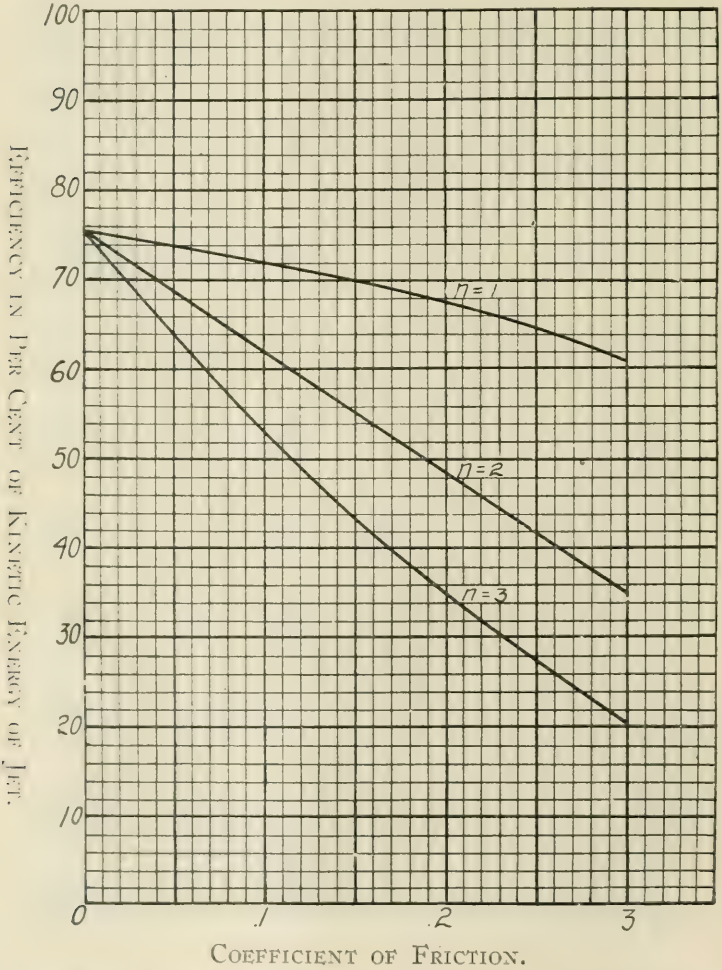


Plate IV.—Curves showing efficiency of a turbine with different coefficients of friction when the angle of the nozzle is 30°.

The curves marked n = 1, n = 2, n = 3, represent the friction efficiency curves for 1, 2 and 3 sets of rotating blades in one pressure stage.

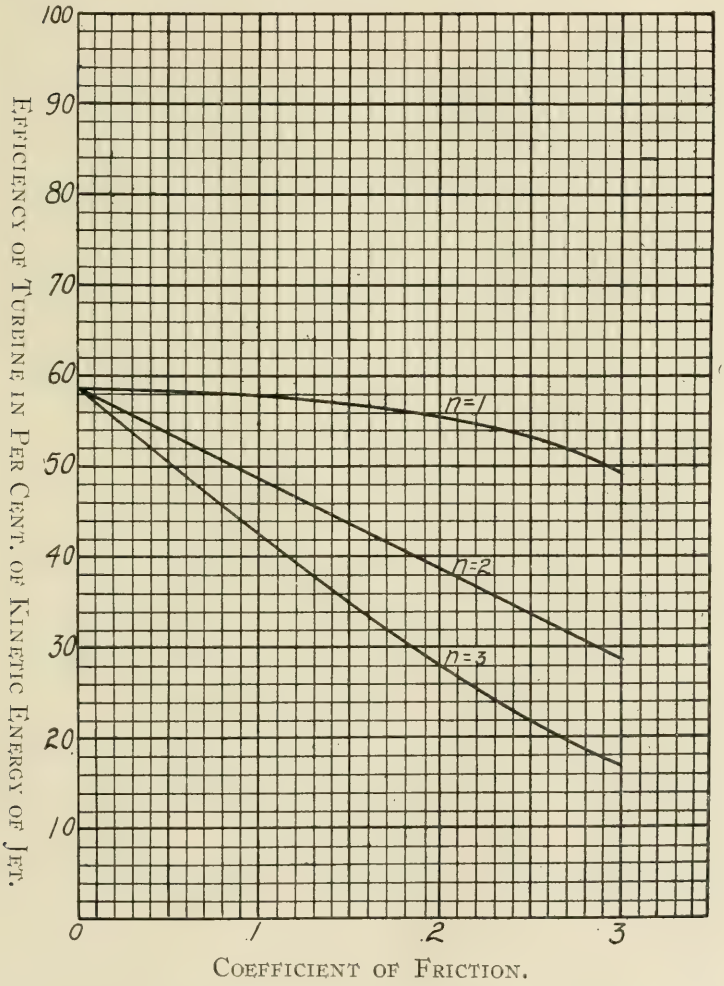


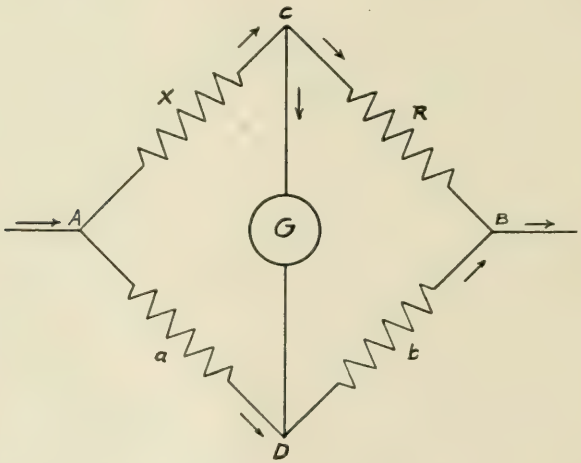
Plate V.—Curves showing efficiency of a turbine with different coefficients of friction when angle of the nozzle is 40°.

A NEW METHOD OF OBTAINING THE FIGURE OF MERIT OF A GALVANOMETER.

By F. C. Brown, Instructor in Physics.

The following discussion explains a new experimental method of obtaining the figure of merit of a galvanometer. The final expression for the figure of merit, i. e. the current necessary to produceduce 1 division deflection on the scale, is given in terms of the resistance in a Wheatstone bridge mesh and the change in deflection produced by a change of 1 ohm in one arm of the bridge.

Let the galvanometer whose figure of merit is desired be connected in a Wheatstone bridge mesh as shown in the following diagram.



Let x, R, a and b be the resistances in the four arms of the bridge.

Let G be the galvanometer resistance.

Let E be the e. m. f. between A and B.

Let e_1 be the e. m. f. between A and C.

Let e_2 be the e. m. f. between A. and D.

then $e_2 - e_1 =$ the e. m. f. between C and D

and by Ohm's law,

$$\frac{e_2 - e_1}{G} = I_g, \tag{1}$$

the current through the galvanometer,
By Kirchoff's Law.

$$I_g = I_x - I_R = \frac{e_1}{x} - \frac{E - e_1}{R} \tag{2}$$

$$I_g = I_b - I_a = \frac{E - e_2}{b} - \frac{e_2}{a} \tag{3}$$

Eliminating e_1 and e_2 from equation (1), (2) and (3)

$$I_g = E \frac{a R - bx}{G(R+x)(a+b) + R\,ba + R\,b\,x + ax\,R + bx\,a} \tag{4}$$

Now if I_g the current through the galvanometer is zero we have

$$\frac{x}{R} = \frac{a}{b} \tag{5}$$

This is the common use of the Wheatstone bridge.

If in equation (4) we let

$$K_1 = G\,b + a\,G + b\,R + a\,R + ab$$
$$K_2 = a\,R\,G + b\,R\,G + R\,b\,a$$

$$I_g = E \frac{a R - bx}{K_1 x + K_2} \tag{6}$$

Taking the derivative of (6) with respect to x,

$$\frac{d I_g}{d x} = - E \frac{b k_2 + k_1 a R}{(k_1 x + k_2)^2} \tag{7}$$

by definition

$$I_g = F \theta \quad \text{or} \tag{8}$$
$$\frac{\delta I_g}{\delta \theta} = F$$

where F is the figure of merit of the galvanometer and θ is the deflection.

Now,

$$\frac{d I_g}{d x} = \frac{\delta I_g}{\delta \theta} \cdot \frac{\delta \theta}{\delta x} \tag{9}$$

substituting (9) in (8)

$$F = \frac{d I_g}{d x} \frac{1}{\frac{\delta \theta}{\delta x}} \tag{10}$$

substituting (7) in (10)

$$F = \frac{E(b k_2 + k_1 a R)}{\frac{\delta \theta}{\delta x} (k_1 x + k_2)^2} \tag{11}$$

In equation (7) it is to be noted that we may neglect the negative sign so long as it is immaterial which way the current changes with increase in x. In equation (11) we are concerned only with the magnitude of the current change.

The calculations in (11) are much simplified by making a = b = R = G. Whence

$$F = \frac{8\,E}{\frac{\delta\theta}{\delta x}(5x + 3a)^2} \qquad (12)$$

If the galvanometer has a high resistance and the change in x (δx) is very small compared to x which is about equal to a, it is often convenient to use the approximate formula,

$$F = \frac{E}{\frac{\delta\theta}{\delta x} \cdot 8a^2} \qquad (13)$$

$\frac{\delta\theta}{\delta x}$ is the change of deflection per ohm change of resistance.

The following is a sample set of data taken in the Junior Physics Laboratory by J. L. Stair. The approximate formula (13) is used.

E volts	δx ohms	$\delta\theta$ mm.	$\frac{\delta\theta}{\delta x}$	a ohms	F amperes per mm.
.68	1	38.0	38	490	$.932(10)^{-8}$
.68	2	76.2	38.1	490	$.930(10)^{-8}$
.68	3	115.8	38.6	490	$.917(10)^{-8}$
.68	4	154.4	38.6	490	$.917(10)^{-8}$
.68	5	192.0	38.4	490	$.922(10)^{-8}$
.68	6	231.6	38.6	490	$.917(10)^{-8}$
				mean value F =	$.923(10)^{-8}$

TABLE SHOWING DATA FOR DETERMINING FIGURE OF MERIT OF A GALVANOMETER.

We will notice from the previous data that the agreement of the results indicates an accuracy sufficient for most galvanometer work. As the factor a enters the equation in the second degree, any error in its determination would make a larger error in the final result. It is evident that four resistances of suitable range are necessary.

However students make most errors in such experimental work from careless contact resistances, such as unclean plugs in the box and in making other connections. One of the particular advantages of this method is that the experimenter is forced to get the value of a about right whether all the box resistances are right or not. Otherwise the galvanometer will not approach balance. But it is not necessary to get an exact balance. The method is then to a large degree self checking.

Of course there will be the same per cent of error in the final result as in the amount of resistance changed. But $\delta\theta \div \delta x$ need not involve much error if four or five observations are taken.

CENTER-BOUND TRACK: A CAUSE FOR SPREADING RAILS.

E. Keough, '08, Civil Engineering.

When the present general form of track was first introduced it was thought that the problem of track construction had been solved. However, as the rolling stock became heavier, much difficulty was experienced on account of light rails, poor rail-fastenings, etc. Various kinds of rails were tried with different degrees of success. To prevent rails from spreading, long clumsy cast iron braces were placed on switch leads, guard rails, and curves. While these braces prevented the rails from moving laterally, they did not hinder them from turning over outward; and consequently they have been replaced with various kinds of shorter and better designed braces.

The steel tie-plate is perhaps the most modern device for holding rails in place, and when well designed and carefully placed, it has, under most conditions, many advantages over the ordinary rail brace. By the use of tie-plates and rail-braces as well as through the general improvement of track structure, many reputable engineers claim that the spreading of rails has been practically eliminated, and that recent accidents, caused by the spreading of rails, were in no way due to defective track.

It is the intention of the writer, however, to show how such accidents may happen even on a first-class rock ballasted road. When a train passes around a curve, the wheels have a tendency to continue in a straight path. Through the front outer wheel of the truck, a lateral force acts on the rail, causing an outward movement of the same. According to Wellington this lateral thrust is equal in magnitude to 75% of the gravity force acting vertically. Under perfect conditions the resultant of these two forces will act at an angle of about 65° to the horizontal. In order to secure and retain this ideal condition, experience has shown that the tie must be so adzed that the rail when first laid, will incline slightly inward. Traffic soon brings the tie and rail into the desired relation and, in so doing, affords a better bearing for the rail. With rails so placed, the friction between the rail and the tie, and the holding power of the

rail fastenings, overcome the lateral thrust and keep the rail in place.

When fine ballast is used the centre of the track is sometimes ridged above the top of the tie with the intention of holding the track in better alignment. This practice is good for its purpose, but it has an accompaning fault. Small particles of the ballast work under the inner flange of the rail and cause an outward inclination of the same. This naturally widens the guage and renders conditions favorable for rail spreading.

Spreading rails seldom give trouble except during frozen weather. When the ballast is not frozen, the rail fastenings and the friction between the rail and the tie force the ties to move outward with the rails at places where the road bed is weak. When the ballast is frozen, however, the ties are held firmly in place through the action of the frost, while the force due to the lurching of the cars causes the rails to move independently of the ties. During freezing weather any small amount of moisture under the base of the rail becomes frost. This reduces the friction between the rail and the tie, and thus allows the most of the lateral thrust to act directly on the outer rail fastenings.With this reduction of friction, a force under normal conditions not at all dangerous, may easily produce a lateral movement of the rails. The spreading of rails is not confined alone to curves, but happens frequently on straight track. This is often due to low rails which cause the cars to lurch toward the lower side, but center-binding is the main cause for all kinds of spreading.

On first class roads accidents due to spreading of rails, caused by either improperly laid rails or bad surface, are few. The worst examples of spreading rails occur on fills or on curves which encircle hills. Such cases are most often caused by center-bound track—track which has a more firm bearing under the centers than under the ends of the ties. Track becomes center-bound on fills because the earth is more compact in the fill under the center than under the ends of the ties. This allows the greatest settlement where the most weight occurs. On double tracked roads the outside rails are over the weakest part of the fill and are invariably the ones which are displaced when spreading occurs. Since the ballast contains more moisture under the center of the track than in the shoulder at the ends of the ties, there will be more heaving by the

frost under the center than at the ends of the ties; and afterwards, the track will become more center-bound than before freezing. As thawing occurs last under the centers of the ties, the resulting ridge of frozen ballast will cause a much greater bearing at the center of the ties than under the rails, and consequently produce a worse form of center-binding. The force of gravity acts through the wheels on these rails in exactly the same manner as in the case of tilting rails on curves or of low rails due to irregular surface. Not only does the center-binding increase, but through the inclination of the ties due to center-binding, friction between the rail and the tie becomes less, and hence the spreading of the track is rendered much more probable.

One of the best roads in the Middle West, during the winter of 1905-06 had an unusual amount of trouble with spreading rails due to this cause. Several places were found where the rail had spread over an inch and a half in a single night. This track appeared to be in first-class condition, and was a portion of the best division on the system, but it had not been surfaced out of a face for several years. Since then this track was given a light, general raise, and the ties were tamped only eight or ten inches inside each rail. Not a single case of spreading occurred during the following winter of 1906-07.

While many trackmen have not recognized the fact that center-binding produces spreading rails, yet some, aware of the cause and the danger, use various means to prevent it. One method used by a few trackmen is to tamp only the ends of the ties the day the track is raised and to finish the center tamping a day or two later. This method has many disadvantages, but the one which concerns center-binding is that the tampers often raise the track slightly by tamping the centers too hard and thus cause what was intended to be avoided, center-bound track. In coarse ballast the track should be tamped only ten or twelve inches inside of each rail; and in ballast which does not drain readily, the centers should be shovel tamped lightly so as to leave no large pockets for water. A good example of a perfect bearing track is that of a well-designed bridge which has the stringers placed outside the rails. Even though soft ties are frequently used without tie plates or braces on such track, spreading never occurs.

In order to secure perfect bearing on fills, embankments and

ballast shoulders should be much wider, and ballast should be dressed level to the full length of the tie to avoid unequal heaving of the ballast under the tie. The ordinary 8-foot tie is thought by many trackmen to be the cause of center-binding on account of the inequality of the bearing surfaces outside and between the rails. On account of the extra amount of material required for making longer ties there will probably be no change until a steel or concrete tie takes the place of the wooden one. A reinforced concrete tie which is now being tried on the Chicago & Alton Ry. is made in such a manner as to have no bearing in the center. This construction not only prevents center-bound track, but requires less material than longer ties and will doubtless prevent track from becoming center-bound.

TESTS OF CHAIN LINKS.

By M. L. Laurence Millspaugh, '07, Mechanical Engineering.

As the uninitiated looks at the ordinary chain, he seldom realizes the difficulties accompanying an analytical investigation of the stresses in each link. Although at the present day chains are used constantly in every branch of engineering work, little is known concerning the forces to which they are subjected. When a chain breaks, it is simply made stronger next time.

So far as known there are only three analytical investigations on record today. Two are by Germans, Winkler and Grashof, while the third is by Professor G. A. Goodenough, of the University of Illinois. Concerning the first two I quote from a discussion of the two theories by Professor Goodenough, who has studied them carefully. "Both are faulty; Winkler, by making an assumption not justified by fact, underestimates the strength of the link. Grashof by incorrect reasoning arrives at results that if adopted would lead to a serious over-estimation of the strength of the link." Hence, neither Winkler's nor Grashof's analysis could be applied to modern engineering practice.

In a thesis presented June, 1900, Professor Goodenough gives an elaborate analytical investigation of the stresses in chain links of different sizes and shapes. The fundamental theory underlying these investigations is contained in Bach's "Elasticitat und Festigkeit." This latter consists of an analysis of the stresses in a hollow cylindrical roller. Professor Goodenough extended the analysis to links with elliptical center lines; links with straight sides; links with stud; links of lemniscate form; and links with center lines of four and six circular arcs, making the circular center line a special case.

The mathematical analysis, being complicated and tedious, is not reproduced. The following is a brief outline of the method of attack. The load on the links is denoted by 2 Q; then considering one-half of the link as a free body the external forces acting are: 1. The pressure of the adjacent link along the surface E F E, the resultant of which must be 2 Q; 2. Stresses in the sections A A at the sides of the link. See Fig. 1. While the resultant of the stress in the section A A has an unknown line of

action, its magnitude must be Q; hence we may replace it by a force Q acting at A′, the center of the section, and a couple of moment M_0. Consider now any other section as C C and let the part of the link between sections A A and C C be the free body. This body is held in equilibrium by the force Q and couple M_0 at the section A A and the stresses in section C C. Since Q acting through A′ does not pass through C′, it will produce a moment at the section C C to

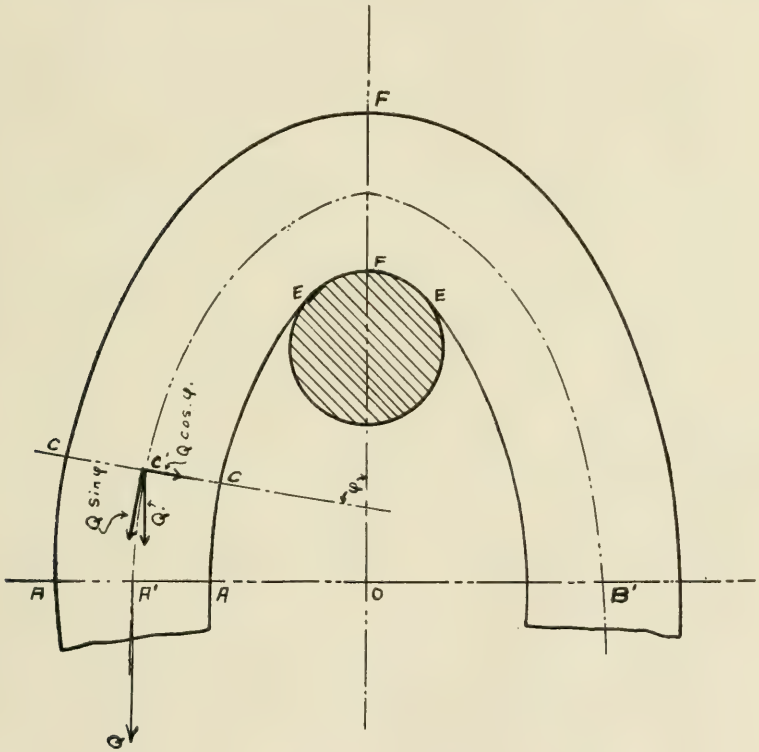


Fig. 1—Showing Method of Analysis.

which must be added the moment M_0. Besides this bending moment at the section C C, there is a force normal to the section of magnitude Q sin ϕ, and a force lying in the plane of the section of magnitude Q cos ϕ, where ϕ denotes the angle which the plane of section C C makes with the major axis O F of the link. The moment is held in equilibrium by a stress couple, the normal force by

a uniform tensile stress, and the tangential force by a uniform shearing stress. As is usual, the shearing stress is neglected in comparison with the normal stresses.

The bending moment M_0 at the section A A is readily determined from certain geometrical conditions; and when this is known it is easy to compute the bending moment and normal force at any section of the quadrant lying between sections A A and F F. With these data the intensity of the stress at any fibre of the section may be found. Considering the line of contact E F E between the links, two assumptions may be made:—1. That the load is concentrated at the point F. 2. That the load is distributed over a certain area E F E. Winkler assumed the point contact; but Professor Goodenough shows in his thesis that this assumption is wrong for ordinary chains. He assumes the line of contact E F E to be the area of distribution of the load. Later, actual experiments have proven the distributed load theory to be correct. In fact with links of ordinary proportions, the action between two links is practically that of a journal and bearing. This distribution reduces in a considerable degree the stresses computed on the assumption that the pressure is concentrated.

These stresses of course can not be measured, but the analysis permits of an estimation of the probable deformation of the axes of the link for any load. Thus in Fig. 1, when the link is placed in tension the points A,' and B,' will move towards the center of the link O, and also towards the point F, due to the stretching of the link. By means of certain formula which comprise part of Professor Goodenough's analysis, we can predict just how much the change will be. This stretching and contracting of the link can also be actually measured by a suitable device when the link is placed in a testing machine. The theoretical and actual deformations can then be plotted, and if the two agree we may assume that the theory is correct.

As a thesis for the degree of Bachelor of Science in Mechanical Engineering, in the College of Engineering, of the University of Illinois, presented June, 1906, Mr. R. M. Evans conducted a series of tests upon several sets of commercial chain links, and applied Professor Goodenough's theory to his results.

Mr. Evans carefully plotted all of his data and obtained several

sets of curves showing the relation between the elongation of the major and minor axes of the links for different loads. Owing to lack of time he was unable to calculate what the curves should be according to Professor Goodenough's theory.

As a thesis for the degree of Bachelor of Science in Mechanical Engineering, to be presented in June, 1907, Mr. R. L. Baker, and the writer have taken up Mr. Evans' work where he left off. It is our intention to obtain theoretical curves for Mr. Evans' data, and further to make another series of tests upon commercial links of various forms. At the present time preparations are well under way for the testings of the following links. Two sets of B. B. B. chain links, 1-inch, 2½-inch pitch. Two sets of B. B. B. chain, 1½-inch, 3⅞-inch pitch. Two sets of Dredge chain, 2-inch, 5¾-inch pitch. Two cast steel rings made especially for these tests. Each ring being 9 inches inside, and 12 inches outside diameter, and 1-inch thick. One wrought iron ring, made as a special forging, of the same dimensions as the two cast steel rings. Two steel rings cut from an extra heavy steel pipe. Each about 8¼-inches outside diameter, ¾-inches thick, and 1-inch wide.

The rings are to be tested with a specially devised apparatus containing knife edges which will give a line contact. Hence, these tests will come under the theory of concentrated load. The commercial links are to be tested under conditions resembling, as near as possible, those of links of a chain in actual use. These tests, therefore, will come under the theory of distributed load. The writer regrets exceedingly that at the time of writing, the results of the above named tests are not available for publication. The computations, however, of Mr. Evans' work are finished and the curves of Plates I, to IV, show some of the results obtained.

Plates I, and II, show the deformations of the major and minor axis of a dredge chain link. This dredge chain was taken from the stock of Jones, Laughlin and Company, Pittsburg; having 1-inch links, with 3¾-inch pitch. Plates III and IV, show the deformations of a conveyor chain link, obtained from the Newhall Iron Chain and Forge Company. The link was taken from stock, and was a 1-inch link with 7-inch pitch. After each link had been tested it was removed from the machine and rested for a few days. Then a second test was run as a check upon the first results. In

plates II and IV only the check tests are shown, as the curves in these cases came too close together to plot on a reduced scale. The curve sheets show that the results are uniform, much more so than could be expected for all of the differences are in .0001 of an inch, which place had to be interpolated, as the calipers read only to .001 of an inch. That no juggling of results occurred during the tests is guaranteed from the fact that Mr. L. E. Moore, Instructor in Theoretical and Applied Mechanics, assisted on the tests by taking down all data as measured. In obtaining the theoretical curves Mr. Baker and the writer each figured out the deformations, thus checking the results. Professor Goodenough also computed the deformations for the conveyor link.

Upon the strength of the results that have already been obtained, the writer feels confident that the experiments which are now well under way will prove conclusively that the fundamental assumptions of Professor Goodenough's analysis are correct.

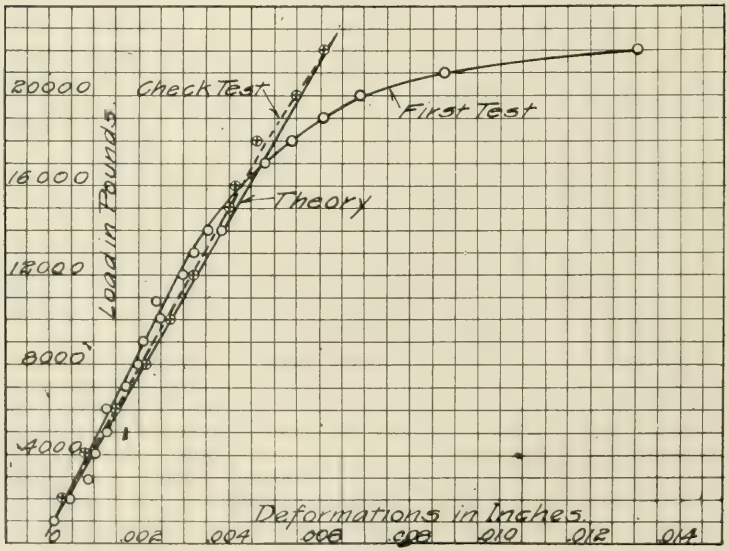


Plate I.
Dredge Chain.

Test 6. Sample 5.
First Test 0. Deformation of Major Axis. Check Test. *
Theoretical Deformations. Distributed Load. Six Arc-Link.

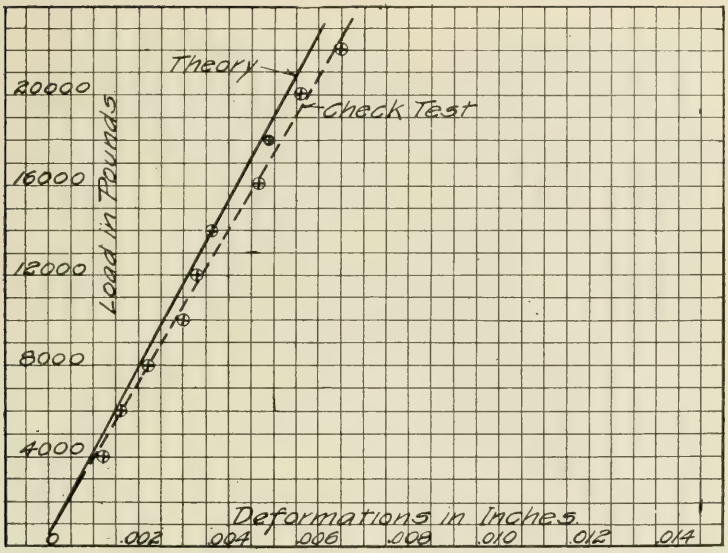


Plate II.
Dredge Chain.

Test 6. Sample 5.
Deformation of Minor Axis. Check Test. *
Theoretical Deformations. Distributed Load. Six Arc-Link.

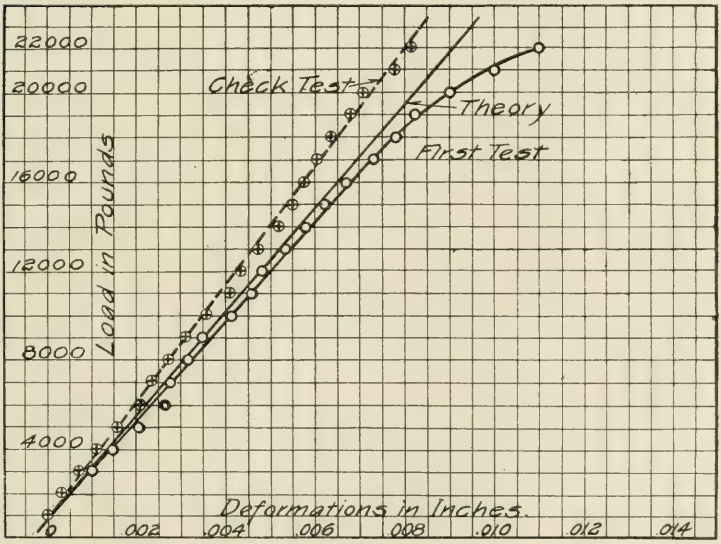


Plate III.
Conveyor Chain.

Test 4. Deformations of Major Axis. Sample 2.
First Test 0. Check Test. *
Theoretical Deformations. Distributed Load. Six Arc-Link.

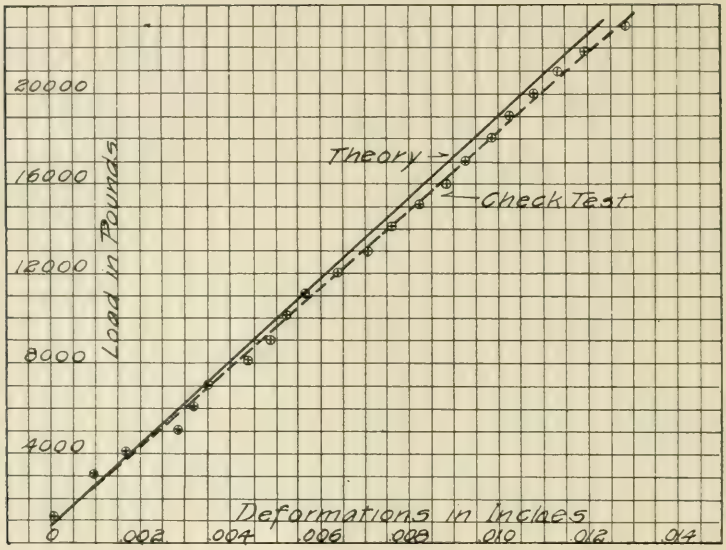


Plate IV.
Conveyor Chain.

Test 4. Sample 2.
Deformation of Minor Axis. Check Test. *
Theoretical Deformations. Distributed Load. Six Arc-Link.

SIMULTANEOUS TELEPHONY AND POWER TRANSMISSION OVER THE SAME WIRES.

By T. H. Amrine, '06 and C. C. Carr, '06,
Electrical Engineering.

The object of this thesis was to devise a method of simultaneous telephony and power transmission over the same wires. Messrs. Amrine and Carr had considerable success in attaining the result aimed at and therfore their discussion of experiments and results is given below.

The advantages of being able to use the wires of a power transmission line for telephony between the substation and the power house or between two substations is obvious. Rendering, as it would, the use of a separate telephone wire on the pole line unnessary, the poles could be made shorter, thus decreasing the cost of construction. However, where there is any danger from the high tension current to the operator using the telephone, the safety of the device is of much greater importance than cheapness of construction. In telephoning over a line which is on the same poles as the transmission line there is danger both from direct connection with the high tension current and from a static shock from the charge held between the high tension wires and the telephone wires. With a telephone wire running parallel to and only a few feet from the high tension wire, a slight accident may make a cross between the two circuits. Moreover, this chance of accidental contact between the circuits, due, for instance, to a broken wire, extends over the entire length of line, which would probably be several miles. It is at the time of an accident of this kind that a telephone is most needed to make reports regarding the accident and to give orders for repairs, but it is then that the use of the telephone, if not impossible, is most dangerous. By using the high tension wires for simultaneous telephony and power transmission and having

Editor's Note.—This article is an abstract of a thesis by T. H. Armine and C. C. Carr, and was prepared for publication by S. P. Farwell, '07.

only an inductive connection between them and the telephone apparatus, the chance of accidental contact of the two circuits is localized to a portion of the circuit that may be thoroughly insulated and protected. For this reason, the danger from direct contact with the high tension current is much decreased. Since no separate telephone wire is used, of course the danger from a static charge is eliminated.

The principle upon which the entire set of experiments performed is based is that the power current has a frequency generally of either 25 or 60 cycles per second while the telephone current has a frequency of from about 300 to 500 cycles per second. A method of separating the rather low frequency of the power current from the high frequency of the telephone current is then the first thing necessary for a satisfactory solution of the problem.

Since a large inductance will act almost as an open circuit for very high frequencies, but will allow a low frequency to pass through with much greater ease, and since a very small condenser has the reverse effect, that is, offers a much less impedance to a high frequency than to a low one, it was thought that the proper adjustment of capacity and inductance would separate the two currents of different frequencies.

The first experiments were conducted for the purpose of finding how small a condenser could be used to talk through satisfactorily and at the same time cut down the low frequency current sufficiently so as not to interfere with conversation. Apparatus was connected as in Fig. 1. In this figure S is a rheostat, C a small condenser consisting of two sheets of tin 14 inches square, separated by a piece of ordinary bond paper, R the receiver, T the transmitter and G is an alternator giving 110 volts at 60 frequency. It was found that the condenser had a capacity great enough to make talking through it possible. When the voltage was cut down to from 50 to 70 volts by means of the rheostat there was scarcely any sound in the receiver from the alternating current, but when the pressure was increased to 110 volts, the sound was more audible, but did not seriously hinder conversation.

The experiment to ascertain approximately the size of inductance necessary to satisfactorily separate the two frequencies was made with connections shown in Fig. 2. L was the inductance, the necessary size of which was to be determined. C a small condenser,

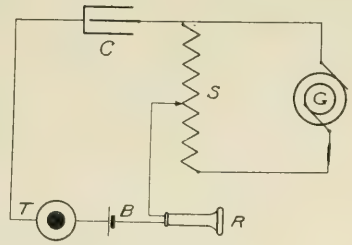


FIG. 1.

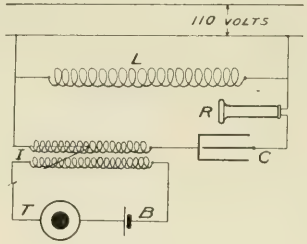


FIG. 2.

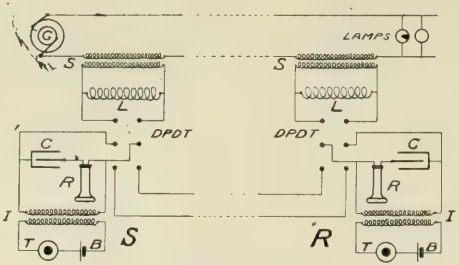


FIG. 3.

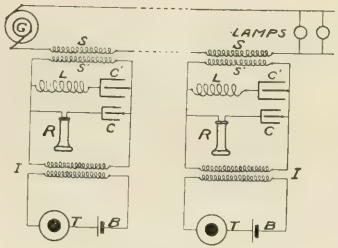


FIG. 4.

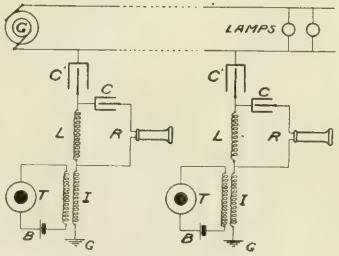


FIG. 5.

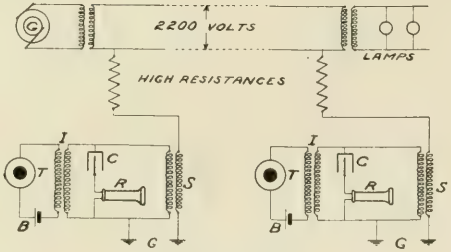


FIG. 6.

SIMULTANEOUS TELEPHONY AND POWER TRANSMISSION

THESIS OF AMRINE AND CARR, UNIV. OF ILL., 1906.

S.P.FARWELL, '07.

and I the ordinary telephone induction coil. It was found that L must be a very large inductance, for instance, that of the primaries of three I-K W. transformers and a condenser at C consisting of only two sheets of tin foil 4 inches square separated by ordinary bond paper was necessary to secure approximate silence of the alternating current.

The connections in Figs. 1 and 2 are not attempts at telephoning over the transmission line, but are simply to give an idea of the size of inductance and capacity necessary for the proper balancing of the low frequency high tension current and the telephone receiver. The first scheme used in the attempt to telephone over the transmission line was that shown in Fig. 3. The transmission line was a 110 volt, 60 cycle line feeding incandescent lamps for a load. S is a series transformer having a ratio of 8 to 1, L is a large inductance consisting of the primaries of three I-K W. transformers. The double pole double throw switch made it possible to throw the telephones together on a direct circuit so that the operators could be in communication whether it was possible to talk over the transmission line or not. C was the small condenser described before and I is the induction coil.

The theory of this scheme is as follows: The high frequency telephone current produced at the transmitter passes through the induction coil and the series transformer out on the line to the other series transformer and into the local telephone circuit at the receiving station R. The high inductance L provides no easy path for this high frequency, so that the telephone current passes on to the receiving circuit containing the condenser. This condenser permits the current to pass through it and the receiver, thus reproducing the sound made at S. The low frequency power current which also comes through the series transformer into the local circuit is short circuited by the inductance L and the secondary of the induction coil I instead of passing through the condenser and receiver which offer a high impedance to the low frequencies.

With this scheme talking was found to be possible over the total variation of pressure used, that is, from 110 volts to 440 volts with equal ease, but the inductance used was large and costly and the balance between the capacity and inductance was lost as soon as the load changed. This, of course, renders this scheme unprac-

ticable, because in practice the load current varies considerably from moment to moment.

An attempt was next made to introduce a condenser in series with L, of such a capacity that for 60 frequency there would be a condition of resonance established in that part of the circuit. The connections are shown in Fig. 4. L, and C were adjusted to resonance as nearly as possible. C was a condenser smaller than any used before, composed of two sheets of tin foil 1¼ inches square with paraffine paper insulation. It was found that by the proper adjustment of L, and C, the system could be balanced almost perfectly for any one load so that no sound of the alternating current was noticeable, but when the load was changed the balance was lost. The trouble lay in the fact that L, must be large in order to keep the voice currents from being shunted around the receiver and consequently the inductance coil L, must have an iron core so as to reduce its size to practicable dimensions. With iron in the core, however, the inductance changes rapidly with the current since the iron is being worked low on the magnetization curve. Hence L, and C′ do not remain in resonance and the scheme is really the same as that of Fig. 3 as soon as the load changes any amount. It looks reasonable that with an inductance at L, without iron the system would remain adjusted for any load. The function of L, C′ is, of course, to provide an approximate short circuit for the low frequency current since the inductance and capacity are in resonance. It helps prevent this current from passing through the receiver R and is aided in this by the very small condenser C. L, C′ is not in resonance for a current of voice frequency and since C′ has a very small reactance for this frequency it is practically the same as a simple inductance which will prevent the voice currents from shunting around the receiver. L, hence must be larger in inductance than the secondary S′ of the series transformer, in fact, what is wanted is a difference of inductance between L, and S′ in favor of L,. This might be done by increasing the inductance of L, and suggested the abolishment of the series transformer and the trial of a scheme using static induction between the line and the local telephone circuit.

In the scheme using static induction, a grounded telephone circuit was used. The connections are shown in Fig. 5. C was the

small condenser used in the last scheme tried and C' was a larger condenser consisting of four sheets of tinfoil about two inches square. I, was an inductance consisting of the low current coil of a Westinghouse 8 to 1 switchboard current transformer. Care was taken to have both grounded telephone circuit on the same side of the line.

For 110 volts on the line, this scheme worked admirably, the talking being very distinct and the alternating current being scarcely noticeable. The load was changed from 2 to 22 amperes with no difference in the talking or in the noise of the alternating current. 440 volts were then tried on the line with 5 lamps in series for a load. While the sound of the high pressure current was not a serious hindrance to talking, it was at once concluded that this system would not be satisfactory for high voltages, because if C were made small enough to cut down the current in the telephone circuit so that the alternating current would not be heard, then it would be so small that it would be impossible to talk through it. Hence this scheme was abandoned.

Two of the schemes described had each been, so to speak, half a success. The one shown in Fig. 3 worked well for any variation of pressure, but it was possible to use it only if the current on the line remained constant. The scheme shown in Fig. 5 was found to be impossible on high voltages, but it would work equally well with any current which was put on the line. An attempt to combine the good features of both schemes resulted in using the connections shown in Fig. 6. S was an ordinary telephone induction coil used as a series transformer. Care was taken to have both telephone stations connected to the same side of the line. The receiver circuits should be grounded as a protection to the person using the telephone in case of failure of the insulation between the two coils of S and a ground on the other side of the line. As a protection to the transmission line in case of a ground on the other side, a high resistance should be introduced in the ground circuit at each end and a high tension circuit breaker introduced. This would give perfect protection to the operator and to the transmission line in case of accidents. A pressure of 110 volts was used at first with this system with a load of two 110 volt lamps. The telephone talked well and the alternating current was almost absolutely quiet. The load was increased to 32 lamps but no difference could be noticed in the sound of the al-

ternating current; it remained very quiet. Four lamps were then put in series and 440 volts were impressed on the line. The sound of the alternating current was no louder than at 110 volts. The load was then increased to four times the former amount, but the talking continued to be very satisfactory. An inductance coil containing iron and of a fairly high resistance was introduced in the line to approximate the conditions in a longer line, but neither the talking nor the sound of the alternating current was changed at all as far as the ear could determine.

All the experiments up to this time had been on the lines in the laboratory, but to try this last scheme on a higher voltage than had yet been tried, an experimental line several hundred feet long was constructed out of doors with a transformer for stepping the pressure up to 2200 volts. The apparatus was put on this line and loads on the secondary of the step-down transformer varying from 1 to 17 amperes were used. The telephone seemed to talk as well as it did over the lower voltage line and the sound of the alternating current sounded no louder than for 110 volts. In fact the scheme worked in a very satisfactory manner and with some refinement in apparatus and adjustments it seems probable that it could be made a commercial success.

FORCE AND MASS REDUCTION.

By Alwin Schaller, '07, Mechanical Engineering.

In many of the problems arising in the kinetics of mechanisms it is convenient, even almost necessary, to reduce the masses under consideration to kinetically equivalent masses at certain chosen points, and similarly to reduce the forces acting throughout the mechanism to an equivalent system of forces having chosen lines of action. In the following paragraphs we shall take up the general principles of force and mass reduction and then show the application of these principles to certain well known mechanisms.

When masses are reduced from one point of a system to another the dynamic conditions must remain the same, that is, the velocities and accelerations of the moving masses must remain unchanged by the reduction. In order that these conditions may obtain, the kinetic energy of the reduced system at any instant must be equal to the total kinetic energy of all the separate masses of the original system moving at that instant.

General expressions which can be used for reducing the mass of a body to any point will now be deduced. The following notation will be used in all subsequent work. Original masses will be denoted by Roman capitals with suitable subscripts; reduced masses with corresponding script capitals, the principal moment of inertia by I and the corresponding radius of gyration by k.

The first case to be considered is the reduction of a rotating mass to any point in the same plane of rotation.

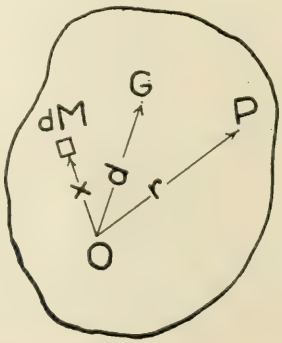


Fig. 1.

In Fig. 1 let:

M = mass of rotating body.
I = principal moment of inertia.
I′ = moment of inertia with respect to axis of rotation.
O = center of rotation.
P = point to which mass is to be reduced.
G = center of gravity.
r = distance from O to P.
d = distance from O to G.
$\frac{d\theta}{dt}$ = angular velocity.

Take any element of mass d M at a distance x from O, and let d M be corresponding element reduced to point P.

The kinetic energy of particle d M = $\frac{1}{2}$ d M $x^2\left(\frac{d\theta}{dt}\right)^2$

The kinetic energy of particle d M = $\frac{1}{2}$ d M $r^2\left(\frac{d\theta}{dt}\right)^2$

Hence

$$\frac{1}{2}\, d\, M\, x^2 \left(\frac{d\theta}{dt}\right)^2 = \frac{1}{2}\, d\, M\, r^2 \left(\frac{d\theta}{dt}\right)^2$$

and therefore $\int d\ M\ x^2 = r^2 \int d\, M$

But $\int\ d\ M\ x^2 = I' = Mr^2$

whence $$M = \frac{I'}{r^2} = \frac{I + M\, d^2}{r^2}$$

This equation stated in words is as follows: *The reduced mass at any point is equal to the moment of inertia divided by the square of the distance from center of rotation to the point of reduction.* The equation may be used for solving various problems relating to rotating bodies; and in many cases the solution is thus considerably simplified. A few examples will serve to illustrate the application.

The body shown in Fig. 2 is made to rotate by a weight W which is fastened to a cord wrapped about a cylindrical portion of the body of radius r. It is required to find the acceleration of the weight and of the rotating body.

Let a = acceleration of W.

α = angular acceleration of rotating body.

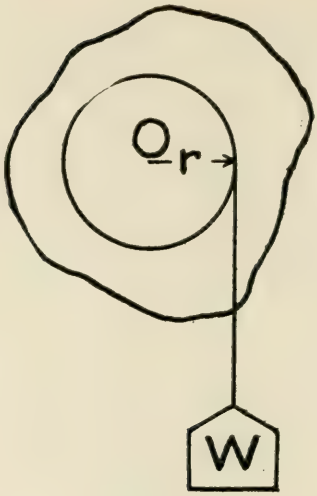


FIG. 2.

Reduce the rotating mass to a point on surface of the cylinder.

The total mass is $\frac{I'}{r^2} + \frac{W}{g}$

The force acting is the weight W.
Since $F = m\,a$.

we have $$W = \left[\frac{I'}{r^2} + \frac{w}{g}\right] a$$

whence, $$a = \frac{W}{\left[\frac{I'}{r^2} + \frac{w}{g}\right]} = \frac{W\,g}{\left[\frac{I'}{r^2} + W\right]}$$

But $a = r\,\alpha$;

therefore $$\alpha = \frac{W\,g}{\left[\frac{I'}{r} + \frac{w\,r}{g}\right]}$$

In Fig. 3 let I′ = moment of inertia of the disc with respect to O.
W = weight of rotating body.
$\bar{r}$ = radius of center of gravity.
r = radius of Q.
R = radius of P.
a = acceleration of P.

W reduced to the radius of P = $\frac{I'}{R^2}$

Total mass moved $\frac{I'}{R^2} + \frac{P}{g} + \frac{Q\,r}{g\,R}$

The forces acting are P, Q and $W\bar{r}\cos\theta$; hence the total force at radius R is $P + \frac{W\bar{r}\cos\theta}{R} - \frac{Q\,r}{R}$

We have therefore $P + \frac{W\bar{r}\cos\theta}{R} - \frac{Q\,r}{R} = \left[\frac{I'}{R^2} + \frac{P}{g} + \frac{Q\,r}{R\,g}\right] a,$

or $a = \frac{P\,R + W\bar{r}\cos\theta - Q\,r}{\left[\frac{I'}{R} + \frac{P\,R}{g} + \frac{Q\,r}{g}\right]}.$

The acceleration for any given angle of θ can now be computed.

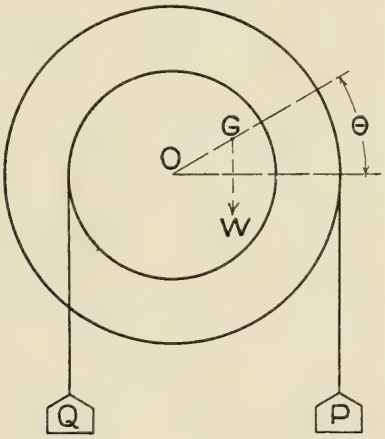


FIG. 3.

The advantage of using reduced masses in the solution of the preceding problems is now evident. The problems can be solved at once from one equation, while if the method of moments is used the acceleration is found by solving simultaneous equations with three or more unknowns.

The second case is the reduction of a mass having motion of translation to a point of a rotating system.

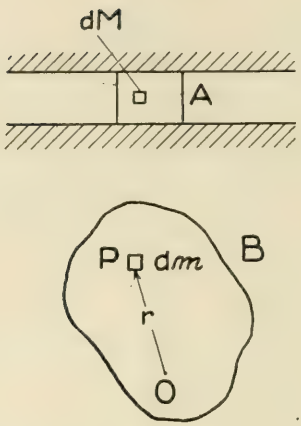


FIG 4.

In Fig 4 let M = mass of body A.

$\frac{dx}{dt}$ = velocity of A.

P = point to which A is to be reduced.

$\frac{d\theta}{dt}$ = angular velocity of B about center of rotation O.

d M = element of mass of body A.

d M = element reduced to P.

Kinetic energy of particle d M = ½ d M $\left(\frac{dx}{dt}\right)^2$

Kinetic energy of particle d M = ½ d M $\left(\frac{d\theta}{dt}\right)^2$

therefore ½ d M $\left(\frac{dx}{dt}\right)^2$ = ½ d M $\left(\frac{d\theta}{dt}\right)^2$

or $M = \frac{M}{r^2} \frac{\left(\frac{dx}{dt}\right)^2}{\left(\frac{d\theta}{dt}\right)^2}$

Before this expression can be determined the relation between $\frac{dx}{dt}$ and $\frac{d\theta}{dt}$ must be known. This relation is given by the geometry of the figure. Take for example the familiar slider crank mechanism.

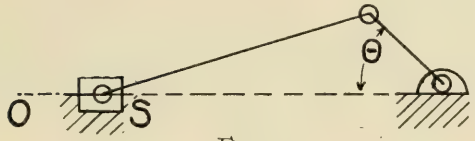


FIG. 5.

In Fig. 5 let r = radius of crank.
l = length of con. rod.
M = mass of reciprocating parts.

It is required to reduce the reciprocating mass M to the radius of the crank. From the preceding equation it is evident that the velocity of the crosshead must be found.

From the figure

$$O\,S = x = r + l - r\cos\theta\,\sqrt{l^2 - r^2\sin^2\theta},$$

whence $\frac{dx}{dt} = r\sin\theta\frac{d\theta}{dt} + \frac{l^2\sin\theta\cos\theta}{\sqrt{l^2 - r^2\sin^2\theta}}\,\frac{d\theta}{dt}$

But $\frac{d\theta}{dt} = \omega$ the angular velocity of the crank.

therefore $\frac{dx}{dt} = r\omega\left[\sin\theta + \frac{\sin\theta\cos\theta}{[l^2/r^2 - \sin^2\theta]^{1/2}}\right]$

now $M = \frac{M}{r^2\omega^2}\left(\frac{dx}{dt}\right)^2$

therefore

$$M = M\left[\sin\theta + \frac{\sin\theta\cos\theta}{[l^2/r^2 - \sin^2\theta]^{1/2}}\right]^2$$

This expression is often simplified by the introduction of approximations which are allowable when the ratio of the connecting rod to the crank is large. This condition obtains when the mass of a valve and valve rod are reduced to the radius of the eccentric, as in the following case.

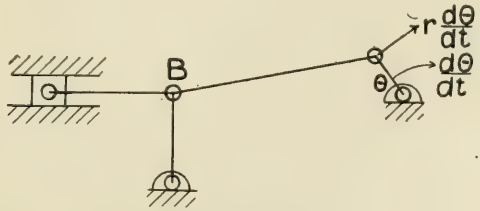


FIG 6.

In Fig. 6 let M = mass of valve and rod.
x = radius of eccentric.
$\frac{d\theta}{dt}$ = angular velocity of eccentric.

then the linear velocity of A is $r\frac{d\theta}{dt}$;

and the velocity of B is approximately $r\frac{d\theta}{dt}\sin\theta$

therefore

$$M = \frac{M}{r^2}\frac{\left(\frac{dx}{dt}\right)^2}{\left(\frac{d\theta}{dt}\right)^2} = \frac{M r^2}{r^2}\frac{\left(\frac{d\theta}{dt}\right)^2}{\left(\frac{d\theta}{dt}\right)^2}\sin^2\theta = M\sin^2\theta$$

The last case to be considered is the reduction of the mass of any link of a machine to some point on another link.

Let: I = principal moment of inertia of link *n* of a system.
I'_{in} = moment of inertia with respect to its instantaneous center.
in = instantaneous center of link *n*.
ω_{in} = angular velocity (about inst. center.)
ip = instantaneous center of *p*.
E = point on link *p* to which *n* is to bt reduced.
r = radius of E from *ip*
ω_{pi} = angular velocity of link *p*.

$I'_{in} = I + M\,[in - G_{in}]^2$

Kinetic energy of link n = $\frac{1}{2}\, I'_{in}\,\omega^2_{in}$
Kinetic energy of reduced mass = $\frac{1}{2}\, M\, r^2\,\omega_{in}{}^2$
Hence $\frac{1}{2}\, M\, r^2\,\omega^2_{pi} = \frac{1}{2}\, I'_{in}\,\omega^2_{in}$

or $M = \frac{I'_{in}\,\omega^2_{in}}{\omega^2_{pi}\,r^2} = \frac{M\,[k^2 + [in - G_n]^2]\,\omega^2_{in}}{r^2\qquad\qquad\omega^2_{ip}}$

To illustrate the use of these expressions just derived we will take an existing flyball governor and reduce all masses to the center of the ball. Two conditions should be carefully noted. The motion of the governor about its own axis is not considered. The fly weight is given a slight movement and the kinetic energy of all of the links is that due to the velocity which is obtained by this motion. It should also be observed that for every expression derived for reduced mass one of the factors always is the ratio of the velocities. This shows that the rate which the mechanism is moving does not affect

the result, because the ratio of velocities of two links depends only upon the geometry of the figure.

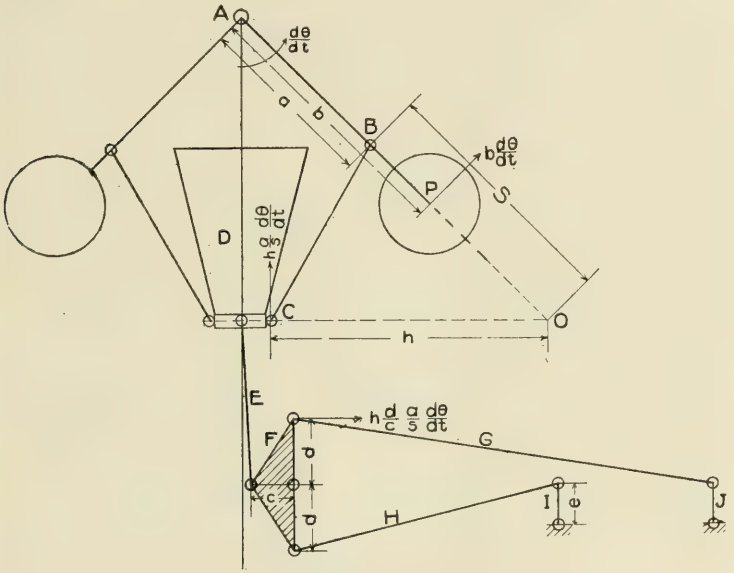


FIG. 7.

Fig. 7 is a sketch of the governor on the York Ice Machine in the Mechanical Engineering Laboratory.

Let: dm = element of mass reduced to P

I = moment of inertia of link A B P with respect to center or rotation.

I_1 = moment of inertia of link C B with respect to instantaneous center of rotation.

M_1 = mass of D.

M_2 = mass of E.

I_2 = moment of inertia of F with respect to center of rotation.

M_3 = mass of G.

M_4 = mass of E.

I_3 = moment of inertia of I and J with respect to center of rotation.

The governor has an angular velocity $\frac{d\theta}{dt}$ about pin A.

Linear velocity of P $= b\frac{d\theta}{dt}$

Kinetic energy of A B P $= \frac{1}{2} I \left(\frac{d\theta}{dt}\right)^2$

Kinetic energy of $dm = dm \frac{b^2}{2}\left(\frac{d\theta}{dt}\right)^2$

Therefore $\frac{1}{2} I\left(\frac{d\theta}{dt}\right)^2 = \Sigma\, d_m \frac{f^2}{2}\left(\frac{d\theta}{dt}\right)^2$

or $M = \frac{I}{f^2}$ mass of link A B P reduced to P.

Link C B rotates about instantaneous center O. Linear velocity of B is $a\frac{d\theta}{dt}$ therefore angular velocity about O is $\frac{a}{s}\frac{d\theta}{dt}$

Kinetic energy $= \frac{1}{2} I_1 \left(\frac{a}{s}\frac{d\theta}{dt}\right)^2$

and as before $\frac{1}{2} I_1\left(\frac{a}{s}\frac{d\theta}{dt}\right)^2 = M_2 \frac{b_2}{2}\left(\frac{d\theta}{dt}\right)^2$

$$M_2 = \frac{I_1 a^2}{s^2 b^2}$$

Point C has linear velocity $h\frac{a}{s}\frac{d\theta}{dt}$ which is also velocity of D and a close approximation to that of E. We shall therefore consider D and E as one body.

We have therefore directly $M_3 = \dfrac{M_1 + M_2\left(h\frac{a}{s}\frac{d\theta}{dt}\right)^2}{b^2\left(\frac{d\theta}{dt}\right)^2}$

$= M_1 + M_2\left[\frac{h}{b} \cdot \frac{a}{s}\right]^2$ (mass of D and E reduced to P.)

The angular velocity of F is $\frac{h}{c} \cdot \frac{a}{s}\frac{d\theta}{dt}$ and its kinetic energy is

$$\frac{I^2}{2}\left[\frac{h}{c} \cdot \frac{a}{s}\frac{d\theta}{dt}\right]^2$$

$$\text{or } \frac{I^2}{2}\left[\frac{h}{c}\frac{a}{s}\frac{d\theta}{dt}\right]^2 = M_4 \frac{b^2}{2}\left(\frac{d\theta}{dt}\right)^2$$

$$M_4 = I_2\left[\frac{I}{b}\frac{h}{c}\frac{a}{s}\right]^2 \quad \text{mas of F reduced to P}$$

The motion of the rods G and H may be taken as a translation. The velocity is $d \cdot \frac{h}{c} \cdot \frac{a}{s} \cdot \frac{d\theta}{dt}$

Therefore $$M_5 = M_3 \frac{\left[d \cdot \frac{h}{c} \cdot \frac{a}{s} \frac{d\theta}{dt}\right]^2}{\left[b \cdot \frac{d\theta}{dt}\right]^2}$$

$$= M_3 \left[\frac{d}{b} \cdot \frac{h}{c} \cdot \frac{a}{s}\right]^2$$

In the same way.

$$M_6 = M_4 \left[\frac{d}{b} \cdot \frac{h}{c} \cdot \frac{a}{s}\right]^2$$

Angular velocity of link I is $\frac{d}{e} \cdot \frac{h}{c} \cdot \frac{a}{s} \cdot \frac{d\theta}{dt}$

and its kinetic energy is

$$\frac{I_3}{2}\left[\frac{d}{e} \cdot \frac{h}{c} \cdot \frac{a}{s} \cdot \frac{d\theta}{dt}\right]^2$$

Therefore $$\frac{M_7}{2} b \left(\frac{d\theta}{dt}\right)^2 = \frac{I_3}{2}\left[\frac{d}{e} \cdot \frac{h}{c} \cdot \frac{a}{s} \cdot \frac{d\theta}{dt}\right]^2$$

$$M_7 = I_3 \left[\frac{1}{b} \cdot \frac{d}{e} \cdot \frac{h}{c} \cdot \frac{a}{s}\right]^2$$

As *I* and *J* are of the same size and have same velocity the last expression also gives the mass of *J* reduced to P.

The addition of the quantities just obtained gives the reduced mass of all links of the governor that accumulate kinetic energy. It is at once evident that this sum varies for each configuration of the mechanism. If this reduced mass were calculated for several different positions and a perpendicular erected upon a straight line base directly below the point P and equal to the quantity thus obtained a smooth curve through these points would give the reduced mass curve. When this curve is once obtained the reduced mass for any position of the governor can be scaled from the curve.

In the preceding discussion analytical methods were used entirely simply for the sake of clearness. For complicated mechanisms however, the expressions for velocities become so long and involved that it is necessary to substitute graphical methods. This may be

done by means of instantaneous centers or velocity polygons. The latter method gives an elegant solution because when a velocity polygon has been constructed it gives the velocity of every point of the mechanism.

Force Reduction.—Whenever a mechanism changes its configuration, energy is imparted to it by forces arising from the accelerations of the moving masses. In order to effect a reduction of these forces to some point the following condition must hold. The energy imparted to the reduced system must be the same as that imparted to the actual system. In other words, the work of the reduced force for any interval of time must be equal to the sum of the works performed by the actual driving forces for the same interval.

Force is usually defined as the action of one body upon another that tends to change motion, either in direction or magnitude. In fact the term force was introduced to account for the observed changes of motion of bodies. Our first conceptions of force are founded on our experience with forces exerted by ourselves.

The first force to be considered acting upon the links of a machine is the force of gravity or simply the weight. The reduction of this force should not be confused with the reductions of the masses, given in a previous paragraph. The remaining forces which arise are due to the accelerations of the moving masses. Let us first consider the simplest case, namely, that of a body rotating about a fixed center, see Fig. 8.

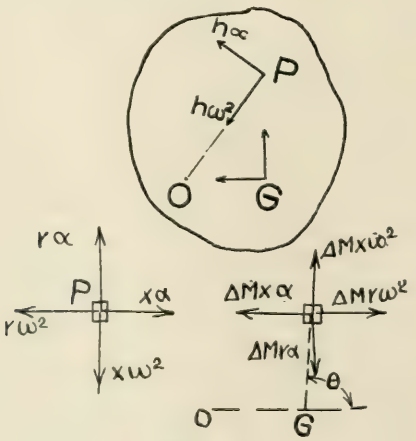


Fig. 8.

Let P be any point,

G the center of gravity;

O the center of rotation;

r the radius of G;

h the distance from O to P;

x the distance from G to P.

Also let ω = angular velocity.

a = angular acceleration.

I = principle moment or inertia.

I′ = moment of inertia with respect to O.

The acceleration at P may be divided into two components the tangential and the normal. The value of the former is h a and that of the latter h ω^2. For convenience of summation, the rotation about O may be replaced by a rotation about G with an equal angular velocity ω, and a translation which must be perpendicular to O G. The acceleration components of P will now be the acceleration due to the rotation about G and the acceleration due to translation which is common to all points of the body. These components are also shown in the figure.

Let Δ M denote an element of mass at point P; the accelerating forces at P are found by multiplying the acceleration components by Δ M. By D'Alembert's principal these forces reversed in sense will hold the external forces acting on Δ M in equilibrium. The reversed forces are in the figure. We will now sum each of these forces for the entire body.

$$\Sigma \, r \, \omega^2 \, \Delta \, M = M \, r \, \omega^2 = F \, r$$

The forces Δ M. r ω^2 form a system of parallel and equal forces, therefore they have a single resultant which passes through the center of gravity The forces r a Δ M are all equal and perpendicular to O G. They therefore have the single resultant.

$$\Sigma \, r \, a \, \Delta \, M = M \, r \, a = F \, r$$

To find the resultant of forces x ω^2 Δ M resolve them into components parallel and perpendicular to O G. Then

$$\Sigma \, x \, \omega^2 \, \Delta \, M \cos \theta = O$$

$$\Sigma \, x \, \omega^2 \, \Delta \, M \sin \theta = O$$

The resultant of this system therefore reduces to zero.

There now remains the forces x a Δ M. The moment of the

force x $a \Delta M$ about G is $x^2 a \Delta M$. The summation gives as the total moment,

$$M = \Sigma x^2 a \Delta M = a \Sigma x^2 \Delta M = I a$$

Therefore in a rotating body we have two forces F_t and F_r which act through the center of gravity and a moment $I a$. F_r is commonly known as the centrifugal force and sometimes as the radial inertia force, F_t is called the tangential inerttia force. The couple $I a$ may be considered as due to the masses resistance to angular acceleration about its own center of gravity.

The total moment about the center O is the sum of the moment of the couple $I a$ and the moment of F_t. (F_r has no moment about O)

$$M \text{ total} = I a + M r a \,.\, r = a [I + M r^2]$$
$$= I' a$$

Therefore to give the body an angular acceleration, about O an external moment of $I' a$ is required.

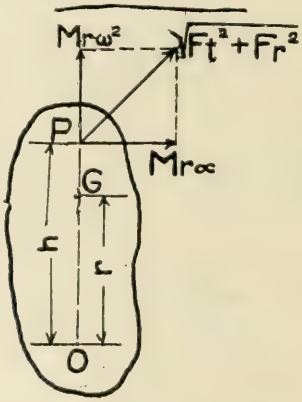


FIG. 9.

F_t, F_r, and $I a$ may be replaced by a single force whose magnitude is $\sqrt{F_r^2 + F_t^2}$ (see Fig. 9) and which acts through a point on the radius drawn through the center of gravity and at a distance k^2 / r. This may be proven as follows:

The total moment about O is $I' a$.

Moment of single force is $M r a h$.

Therefore $M r a h = I' a$

whence,
$$h = \frac{I'}{M_r} = \frac{M K^2}{M r} = \frac{k^2}{r}$$

The expressions just deduced may be applied to a body rotating about an instantaneous center. Let A B be the link of a machine rotating about some instantaneous center. Let $A A_1$ and $B B_1$ be accelerations of A and B respectively (see Fig. 10). From the ac-

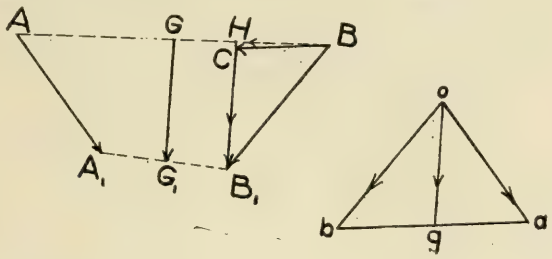


FIG. 10.

celeration polygon the magnitude and direction of the acceleration of the center of gravity may be found. We may replace the motion of A B by a rotation about G and a translation perpendicular to the line joining G and the instantaneous axis. The acceleration of any point will now be made up of two components, one due to the rotation about G and the other due to translation. G's rotational components is zero therefore G's acceleration is that due to translation and is common to all points of the body. Resolve $B B_1$ into components B C and $C B_1 = (G G_1)$, B C is the rotation component. If B C is again resolved into components perpendicular and parallel to A B the tangential acceleration of B, H C, may be obtained.

We have then $\frac{HC}{GB} = a$ angular acceleration about G. In the preceding paragraph we found that the inertia forces of a rotating body were composed of a single force through the center of gravity and a couple. This force had a direction opposite to that of the total acceleration of the center of gravity and its magnitude was the mass of the body multiplied by the acceleration of the center of gravity. In this case we have therefore a force Q through G and a couple $I a$ as shown in Fig. 11. The force and couple may be replaced by a single force whose action line is parallel to Q but does not pass through G. Through a point at a distance c from Q in-

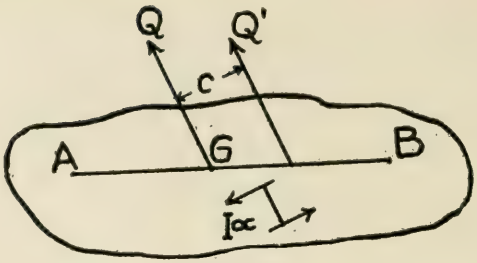


FIG. 11.

troduce a force Q′ equal and parallel to Q. The moment of Q′ about G is Q′c.

But $Q'c = I\ a$

therefore $c = \frac{I\ a}{Q'}$

This equation gives the distance through which the action line must be shifted from the center of gravity in order to produce the given acceleration. Q′ = mass × acceleration of G, a can be found by method already shown. All terms being known c can be readily calculated.

A still more general case is that in which a point moved in a path which has some plane motion not a translation. An illustration is a point on the pendulum of a shaft governor. This moves in a the point is not the resultant of the acceleration of the path, and the circle about the center of suspension and the whole circle has a

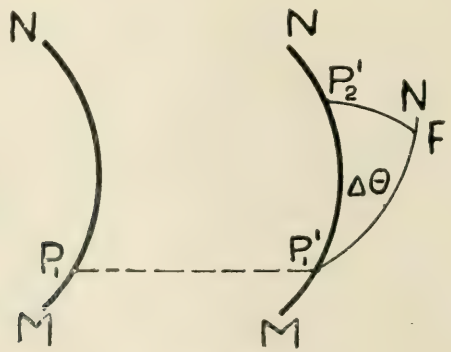


FIG. 12.

motion about the engine shaft. In this instance the acceleration of point in the path, but is instead the resultant of these two plus a third component which we shall proceed to find. In Fig. 12 the motion of point P from P_1 to its final position P_2 is made in three steps. First a translation of path M N, then motion in the path $P'_1 P'_2$, then a rotation of the path through an angle $\Delta\ \theta$.

Let $\Delta\ S$ = length of path traversed by P.

a = acceleration due to rotation of path.

We have then

$$P'_2\ P_2 = \tfrac{1}{2}\ a\ \Delta\ t^2 = \Delta\ s\ \Delta\ \theta$$

$$a = 2\ \frac{\Delta\ s.}{\Delta\ t}\ \frac{\Delta\ \theta}{\Delta\ t}\ \text{approximately.}$$

In the limit therefore

$$a = 2\ \frac{d\ s}{d\ t} \cdot \frac{d\ \theta}{d\ t}$$

Now $\frac{d\ s}{d\ t}$ is the velocity of the point along the curve and is usually denoted by u, and $\frac{d\ \theta}{d\ t}$ is the angular velocity of the curve and is denoted by ω.

Therefore $a = 2\ \omega\ \omega$. The direction of this third component is the limiting direction of $P'_2\ P$, which is normal to the curve or in other words perpendicular to the relative velocity. The total acceleration of P = acceleration of path, plus acceleration of P in the path plus $2\ u\ \omega$. This last acceleration is known as the supplementary acceleration component.

The most general application of Coriolis' law is to motion in space. In plane motion, it will be remembered, the motion of the path was replaced by a translation and a rotation about an instantaneous axis perpendicular to the plane of motion. For motion in space the instantaneous axis is generally inclined at angle θ with the path. This introduces another factor in the expression for acceleration. To make this application clear a particular example will be taken up. Consider the fly ball governor shown in Fig. 13.

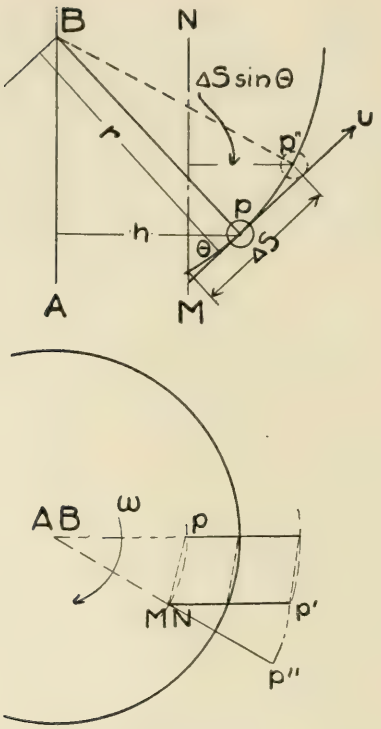


FIG. 13.

If the governor changes its configuration, the masses will have an acceleration in the plane of the governor's motion and also an acceleration in a perpendicular plane, about the axis A B. Divide the motion of point P from p to p″ into a rotation about B and translation to p′ and a rotation about the instantaneous axis M N from p′ to p.″ We now have:

Acceleration of P = acceleration along the path plus acceleration of path plus supplementary acceleration.

Supplementary acceleration component = component due to rotation from p′ to p″

$$p'\,p'' = \tfrac{1}{2}\,a\,\Delta\,t^2 = \Delta\,\Phi \times \text{radius}.$$

But radius $= \Delta\ s \sin\theta$

therefore

$$\tfrac{1}{2}\,a\,\Delta\,t^2 = \Delta\,\Phi\,\Delta\ s \sin\theta \text{ approximately.}$$

In the limit, therefore

$$a = 2 \frac{ds}{dt} \cdot \frac{d\theta}{dt} \sin \theta$$
$$= 2 u \omega \sin \theta$$

We now have

$$\text{Acceleration of P} = \frac{du}{dt} + \frac{u^2}{r} + h\alpha + h\omega^2 + 2 u \omega \sin \theta,$$

the + signs indicating geometrical addition. These components are shown in Fig. 14.

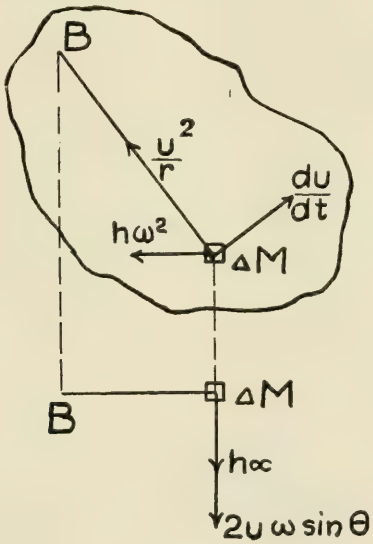


FIG. 14.

Let Δ M denote the particle of mass at P; then the accelerating forces at *P* are found by multiplying the acceleration components by Δ M. By D'Alembert's principle these forces reversed hold the external forces in equilibrium. We have not to sum each of these for the entire mass. The forces Δ M h *a*, Δ *M* 2 u ω sin θ and Δ *M* $\frac{u^2}{r}$ act either perpendicular to the plane of the governor's motion or through the center of rotation B. Hence they do no work in moving the governor and may be dropped from further consideration. As the tangential acceleration $\frac{du}{dt}$ is very small the effect of the force

$M \frac{d u}{d t}$ is negligible, compared with the large centrifugal force which will not be considered. By summation we get

$$\Sigma d F_r = \Sigma \Delta M h \omega = \omega^2 \Sigma \Delta M h$$

But

$$\Sigma \Delta M h = M b$$

therefore

$$F_r = M b \omega^2$$

Although the forces $2 u u\omega \sin \theta \Delta M$ and $h \alpha \Delta M$ act in a plane perpendicular to the governor's motion and do not effect the governing action yet they exert an influence upon the motion of the engine. These inertia forces must be overcome by the turning moment on the crank shaft, just as the inertia of the fly-wheel and other moving masses must be overcome.

A general equation which can be applied for reducing forces will now be derived. The principal of force reduction has been given as the equality of work. In order to systematize and simplify our work, the following notation will be used. Original forces will be denoted by Roman capitals and the reduced forces by corresponding script capitals. The velocity of the point of application of the original forces will be denoted by v′ and the velocity of the point to which they are reduced by v.

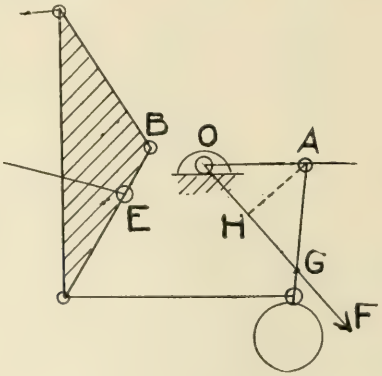


FIG. 15.

Take for illustration the centrifugal shaft governor shown schematically in Fig. 15. Required to reduce force F to point E perpendicular to B E. From A drop a perpendicular A H, to action line O G. Take H as the point of application of force F. To find the work of force F for an instant of time, its magnitude is multiplied by the velocity of H and the product by a differential element

of time. The work of the force F is there fore F v′ d t. Because velocity multiplied by time gives distance and the product of force and distance gives work. The work of the reduced force at E is F v d t.

Therefore F v d t = F v′ d t.

This equation can be used for reducing all of the forces which arise when a mechanism is in motion. The magnitude and method of determining these forces has already been given.

Reduction of the Link Weight Considered as a Force.— Using our previous equation we have at once

$$G_n \text{ u d t} = \text{G}_n \text{ v}' \text{ d t}$$

$$G_n = \frac{\text{G}_n \text{ v}'}{\text{v}}$$

The sign of this force is positive or negative if it helps or hinders the existing motion. Or, in other words, it is positive when it has a component acting in the direction of the path of the center of gravity.

Reduction of the Radial Inertia Force.

Let F_r = radial inertia force, then

$$F_r \text{ v d t} = \text{F}_r \text{ v}' \text{ d t}$$

$$F_r = \frac{\text{F}_r \text{ v}'}{\text{v}}$$

The sign is determined in the same way as in preceding case.

Reduction of Tangential Inertia Force.

Let F_t = tangential inertia force, then

$$F_t \text{ v d t} = \text{F}_t \text{ v}' \text{ d t}$$

$$F_t = \frac{\text{F}_t \text{ v}'}{\text{v}}$$

Reduction of the Angular Inertia Resultant.

Let I a moment of inertia couple.

ω = angular velocity of link under consideration.

Then

$$F \text{ u d t} = \text{I } a \text{ } \omega \text{ d t}$$

$$F = \frac{\text{I } a \text{ } \omega}{\text{v}}$$

The sign of this force is found from the consideration that each link has an angular acceleration about its own center of gravity. If the inertia couple thus developed helps the existing motion, the value of the reduced force is positive, if not the reverse is true.

CONCRETE INSPECTION.

By William Walter Smith, '07, Civil Engineering.

The enormous use of concrete in construction work and the too frequent startling results attained by poor or indifferent workmanship, have created a new opening for employment—that of concrete inspector. Since much of this construction work is begun in summer and finished before frost time, this field offers attractive and remunerative opportunities to undergraduates.

A concrete inspector need not be an individual of broad experience, but he must be a person with a fund of common sense and and unswerving obedience to orders. Doubtless here too, he will meet that annoying question of "experience;" yet, if he has kept his eyes open when about concrete construction, has turned a few shovelfuls, knows the meaning of a 1 : 3 : 6 mixture and that the proper consistency "depends"—, such a man can claim "limited experience" sufficient to qualify as an assistant inspector. Understand! concrete inspection is not play; it is work, work of grave responsibility. One need only review the papers of the past year to understand what havoc has been wrought by poor concrete construction.

The primary duty of the inspector is to see that the work is executed in accordance with the plans and specifications. Therefore he must familiarize himself with their details and always have copies on the work. So armed he can talk over intelligently all points with the foreman. The latter, and not the inspector, is the "boss" of the workmen; yet the inspector, by using tact, may accomplish results even unattainable by the foreman. Under no circumstances should he be suspicious or faultfinding, or assume that the contractor intends to do bad work. On the other hand, no matter what be the influences of good-fellowship, he must be alert and ever watchful for his employer's interests. Nothing resembling bad workmanship should be tolerated in the structure.

More important to the inspector than the purchase of boots or corduroy "pants" is the possession of a note book—two note books. The company will doubtless furnish one for the data demanded in their daily, weekly, and monthly reports,—facts concerning the

work train, the receipt of materials and the total on hand, the yardage of wet and dry excavation, the daily placement of concrete, the number of men employed, etc. It is well to post this book every night and to have reports in on time. In his private book the inspector should copy all facts required by his employer and all other additional items, though seemingly trivial, concerning the number of men and hours employed, the wage, the amount of lumber used and ruined in forms, the outputs, the expense, and the price and cost of everything. Such information will be of unexpected value in future classroom work and later in business.

The inspector will perhaps have little to do with the materials except receiving and listing them. As a general rule, everything should be located about the work with a fore-thought as to future convenience. Cement, necessarily, is placed in a waterproof building, the floor of which is well out of the way of flood waters. The company will furnish instructions concerning samples for testing.

In laying out the structure, it is often impossible to obtain an instrument; yet, for most work, a good tape will suffice. Pencil plans and sketches in the note book will induce accuracy and expedite the work. Incidentally such plans and sketches are good evidence to the company's engineer of the inspector's interest and efficiency.

A yard of earth in place and a yard on the dump are, to the trained eye, entirely different quantities. A young inspector had best prepare his daily estimate from a measurement of the hole; and, as wet excavation costs more than dry, he must obtain his immediate superior's distinction between the two. Usually all earth wet excavation. Judgment should be exercised in dumping the dirt so that it will not interfere with future work.

During the building of the forms the inspector will not be very busy. With an engineer's level he will give the carpenter only the necessary elevations for beginning the work, usually one. He will obtain all others with his spirit level. His mistakes in so doing are not the inspector's, but it is the latter's duty to find them. This is a good time to become better acquainted with the plans and specifications and to formulate some ideas as to computing the cubic content of the structure. It may be possible, at this stage of the work, to make some measurements, such as diagonals, that may save an immense amount of work and worry in future calculations.

Much practical knowledge can be obtained from watching a

skillful carpenter and checking his work. Results which he obtains with his metal square will be the more surprising to one who, to verify them, must draw upon his years of mathematical training. The best lumber should be used for the exposed parts of the structure.

The specifications will doubtless designate the proportions of the concrete; and, if machine mixed, an automatic device will care for this part of the task. However, even machines need some superintendence. If the mixing is done by hand, the wheelbarrow is a convenient unit of measurement, or a bottomless box with handles may be used.

In the hand process of mixing, the cement is spread upon the layer of sand and both turned by four men working as pairs and in unison at either end of the batch. Thorough mixing can not be determined by the number of turnings, yet two will usually be sufficient, provided a spreading, dragging stroke is used. Good mixing can be judged only by the uniform color of the mass, and the inspector must demand this uniformity whether it takes two or ten turnings.

The stone, previously moistened in the wheelbarrows, is spread upon the mixture of sand and cement. Water should be applied only from buckets with sprinkler attachments or from a hose with a spray nozzle. This protects the cement from being washed away. The entire mass is turned once; and, after a second application of water in sufficient quantity to bring the concrete to the proper consistency, it is turned again. The proper consistency depends upon the rapidity with which the concrete is desired to set and the personal opinion of the engineer in charge. Dry concrete sets more quickly than wet, but the wet eventually attains the greater strength. A very safe mean in consistency is possessed by concrete which, when tamped in place, shows a thin layer of floating cement.

Inexperienced inspectors may be a little backward on insisting upon the tamping and spading of concrete. Tamping produces density and thereby adds strength. In order to give a smooth, finished appearance to exposed parts a spade is run down and worked back and forth between the green concrete and the walls of the form. This allows the mortar to run in and to hide the unsightly stone. Better still and less needful of constant supervision is the use of facing irons or boards which hold back the concrete and leave space

for a mortar filling. In either case concrete must not be deposited in layers thicker than six or eight inches; and it is not good practice to drop it from heights greater than say eight feet. Concrete should never be run down troughs, as the larger particles attain greater velocity than the mortar and fall to themselves.

One-half yard of stone, one-fourth yard of sand, and one-twelfth yard of cement do not make five-sixths of a yard of concrete. The most practical way of estimating yardage is to base daily reports upon the space filled by one batch and a careful record of the number of batches. Inspectors soon learn, personally, to count over the empty cement sacks, noon and night, and to check the number with number of sacks required for the batches of cement made. There have been foremen who "forgot" to use the third sack when three were required for a batch. However, it is far from wise to jump at hasty conclusions, as laborers have been known to appropriate empty sacks for their own use.

At the close of the day's work incomplete layers of concrete should be cut off squarely and closed with a temporary bulkhead. Upon renewing operations and also after floods, before placing green concrete, the bulkhead should be removed and the entire exposed surface of the concrete and of the immediate walls of the forms should be wet and scrubbed down with a wire broom. This insures a good union. Concrete which has taken initial set before being placed must not be used in the work.

Many questions will come up on points not covered by instructions. In such matters the inspector must exercise his common sense and judgment. However, in things of considerable import, such as even the smallest change in plans, in existing structures, or of stream channels, he should consult his immediate superior. Since it is the inspector's duty to aid the foreman in every way possible, the latter will often ask his opinion as to the best way to do some part of the work. The inspector should be very guarded in his answers, carefully state that his replies are merely suggestions, and insist that all he wants is results and that the foreman may attain them in the way he thinks best.

On all occasions treat all men as men whether they have been to college or not. From the ordinary laborer the green college man may learn much, and success depends largely upon the ability to handle men.

MEASUREMENT OF BOILER FEED WATER.

By H. F. Godeke, '05, Instructor in Mechanical Engineering Laboratory.

The amount of feed water used is perhaps the most important observation to be made in a steam boiler trial. For that reason care must be taken to see that all the water that goes to the boiler, and only that water, is charged to it. It is quite often the case that the water piping connects to all the boilers in the plant, with only a valve separating each boiler from the water main. This valve usually leaks, and, although special piping is used for the boiler trial, water from the main gets into the boiler. The only safe method is to cut or disconnect the pipe leading from the main to the boiler to be tested. It is well in installing the piping to the boilers to bear this in mind, so that connections may be made with this end in view.

One very satisfactory arrangement of piping which will not have to be disconnected, is shown in Fig. 1. The advantage of this

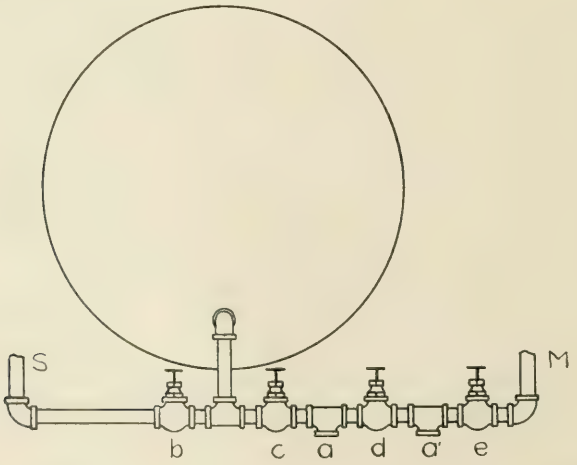


Fig. 1.—Feed Water Piping Arranged for Testing.

scheme may be seen at a glance. a and a′ are two tees opening downward and which are plugged when the boiler is getting its supply of water in the regular way; b, c, d and e are valves controlling the

passage of the water. In running the test, water is taken from the special pipe S and valve b is opened, while valves c, d and e in the main are closed and the plugs in the tees a and a′ are removed. Any water that may leak through the valve c is let out at the tee a while that leaking through the valve e is let out at the tee a′, the valve d serving to keep the water from a and a′ separated. The same arrangement may be used in the blow-off pipe so as to guard against unknown leaks there.

The measurement of the feed water is usually done in tanks of known capacity, fitted with quick opening valves. The use of water meters for this purpose being far too inaccurate. Being thus satisfied that the water measured is the correct amount which has been fed to the boiler, the next step is to see that all the water fed to the boiler has been evaporated, and, if not, the necessary corrections must be made.

In the code adopted by the American Society of Mechanical Engineers for testing steam boilers "Item No. 57", which reads "Total Weight of Water Fed to Boiler," is somewhat misleading. The item is based upon the governing conditions of the code; viz. that conditions as to pressure and height of water on the gage glass, are the same at the close of the test as they were at the beginning. The code is also based upon the conditions of no water-back in the furnace, and no separator between the boiler and the calorimeter, and no leaks.

The fundamental object of a boiler trial is to obtain the efficiency of the boiler; i. e., the number of heat units taken up by the boiler in comparison with the number of heat units furnished it. In order to secure this, "Item No. 57" must be corrected so as to take care of all the heat units used.

In the case where a water-back is used in the furnace there may be some question as to whether or not the boiler should be given credit with the heat units collected by the water-back, but as these heat units are collected at the expense of the fuel charged to the boiler, it is certainly proper that this credit should be given.

It sometimes happens that there is a separator on top of the boiler, between the boiler and the calorimeter. It is not right to give the boiler credit for having evaporated the water which is entrained from the separator, but at the same time credit must be given to the boiler for the heat which it has imparted to this water.

The same reasoning may apply to any water that has leaked past the blow-off valve.

The heat units collected by the water passing through the water-back, those contained in the water taken from the separator between the boiler and the calorimeter, or from leaks, and those contained in the excess water in the boiler at the close of the test, must be put into a form so that they can be used in computations; and since there is no other place provided in the code, the corrections are to be made in "Item No. 57."

The excess water in the boiler at the end of the test, as well as the water entrained from the separator, or leaks, has been raised in temperature from that of the feed water to that of the liquid in the boiler, hence the heat put into each pound is $(q - h)$, where q is the heat in one pound of the liquid at boiler pressure and h is the heat in one pound of feed water.

If, on the other hand, there is less water in the boiler at the close of the test than at the beginning, heat has been used in evaporating that water, the amount of heat used for each pound being $(H - X L - q)$, where H is the total heat in one pound of saturated steam at boiler pressure, L is latent heat of steam at boiler pressure, and X is the moisture in the steam.

The water passing through the water-back has been raised in temperature from that of the entering water to that of the leaving water, hence one pound has consumed $(t_2 - t_1)$ heat units, where respectively.

Suppose the conditions of initial and final boiler pressures are not the same. If the pressure has increased, the water in the boiler contains more heat units than at the start, while if it has fallen, it contains fewer than at the start. The heat put into one pound of water that has been evaporated into "moist" steam is $(H - X L - h)$.

We will now transfer the various conditions referred to above, so as to place them in condition for handling, denoting initial conditions by the subscript i, the final by f and the average by av.

(1) Water-Back.

Total water passing through Water-back $= W'$

Heat in same $= W' (t_2 - t_1)_{av}$

(A) Equivalent lbs. of moist steam $= \dfrac{W' (t_2 - t_1)_{av}}{(H - X L - h)_{av}}$

(2) Water entrained from separator or leaks.
Total water collected = W''
Heat in same = $W''\ (q - h)_{av}$

(B) Equivalent lbs. of moist steam = $\dfrac{W''\ (q - h)_{av}}{(H - X L_{\prime} - h)_{av}}$

(3) Excess Water in boiler at close of test.
Excess water = W'''
Heat in same = $W'''\ (q_f - h_{av})$

(C) Equivalent lbs. of moist steam = $\dfrac{W'''\ (q_f - h_{av})}{(H - X L_{\prime} - h)_{av}}$

(4) Lower water level in boiler at close than at beginning of test.
Difference in water = W^{iv}
Heat used in evaporating same = $W^{iv}\ (H_{av} - XL_{av} - q_i)$

(D) Equivalent pounds of moist steam =

$$\frac{W^{iv}\ (H_{av} - XL_{av} - q_i)}{(H - XL_{\prime} - h)_{av}}$$

(5) Heat due to change of pressure in boiler.
Total heat = $W^{v}\ (q_f - q_i)$ where W^{v} is the *Initial* or *Final* weight of water in the boiler according as to whether there is more or less water in the boiler at the close than at the beginning of the Test.

(E) Equivalent pounds of moist steam = $\dfrac{W^{v}\ (q_f - q_i)}{(H - XL_{\prime} - h)_{av}}$

Note.—This will be a negative quantity in case the final pressure is less than the initial pressure.

"Item No. 57" corrected should now be $W - W'' - W''' + (A) + (B) + (C) + (D) + (E)$ where W is the amount of water fed to the boiler.

EXPLOSIVE PROPERTIES OF GASEOUS MIXTURES.

By Allen B. Cooke, '07, Mechanical Engineering.

Experiments bearing on the subject of the "Explosive Properties of Gas and Gasoline Vapor Mixtures" were made for a thesis by Mr. Allen of the University of Illinois in 1901. The Massachusetts Institute of Technology also made experiments on the same general subject in 1900. A brief review of these experiments will be given here.

Mr. Allen's experiments were performed with a closed iron cylinder nine inches in diameter and eighteen inches long. To this cylinder were attached an indicator, of the ordinary gas engine type, a tuning fork actuated by an electric magnet to make a time wave on the indicator card as it was caused to rotate by a weight, a gage for measuring the initial pressure, and the necessary batteries and weights. A known weight of gasoline was introduced into an enlargement of the air supply pipe and the air was then driven into the cylinder over the gasoline, thus froming the vapor mixture. This mixture was further mixed by a fan rotated within the cylinder. The air was obtained from a compressor, thus enabling different initial pressures to be experimented with. In the trials for the effect of neutral dilution, one cylinder full of the burned gases from the previous explosion was left in the cylinder at atmospheric pressure.

The experiments of the Massachusetts Institute of Technology were performed only on mixtures at atmospheric pressure but since all experiments to the present time show that doubling the initial pressure doubles the final pressure, the experiments are of just as great value as if different initial pressures had been used.

Mr. Allen points out the following things in connection with his experiments: The effect of having neutral dilution, or the presence of old burned gases in the cylinder, is very marked. Explosion can not be had so readily nor at so low a pressure as with pure gases. In fact, at low pressures the diluted mixture refused to explode at all. This is due to the fact that at low pressures the proportion of burned gases is greater than at high pressures. The maximum pressure is greatly reduced by the dilution. This may be clearly seen from

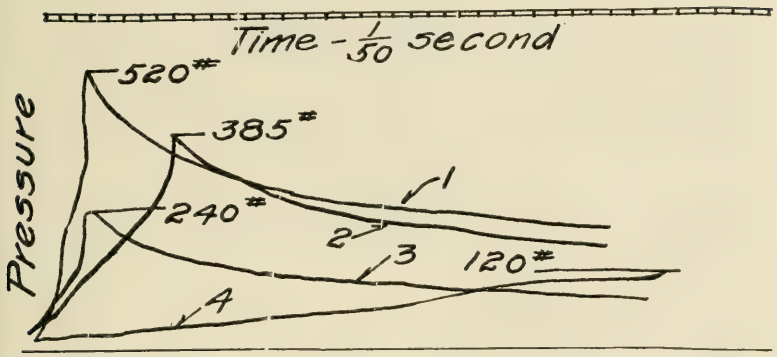


FIG. 1.—TIME PRESSURE CARDS

1. Initial Pressure 50 lbs. per sq. in. Pure.
2. Initial Pressure 50 lbs. per sq. in. Diluted.
3. Initial Pressure 20 lbs. per sq. in. Pure.
4. Initial Pressure 20 lbs. per sq. in. Diluted.

the indicator cards in Fig. 1. Figs. 2 and 3 show the effect of various mixtures upon the maximum pressure and time of explosion. The rate of combustion is so much retarded by the presence

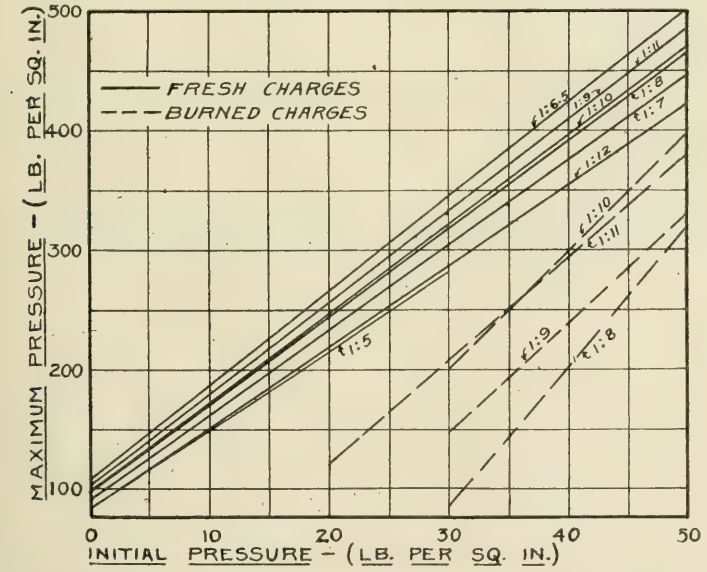


FIG. 2.—CURVES SHOWING EFFECT OF VARIOUS MIXTURES OF GASOLINE AND AIR.

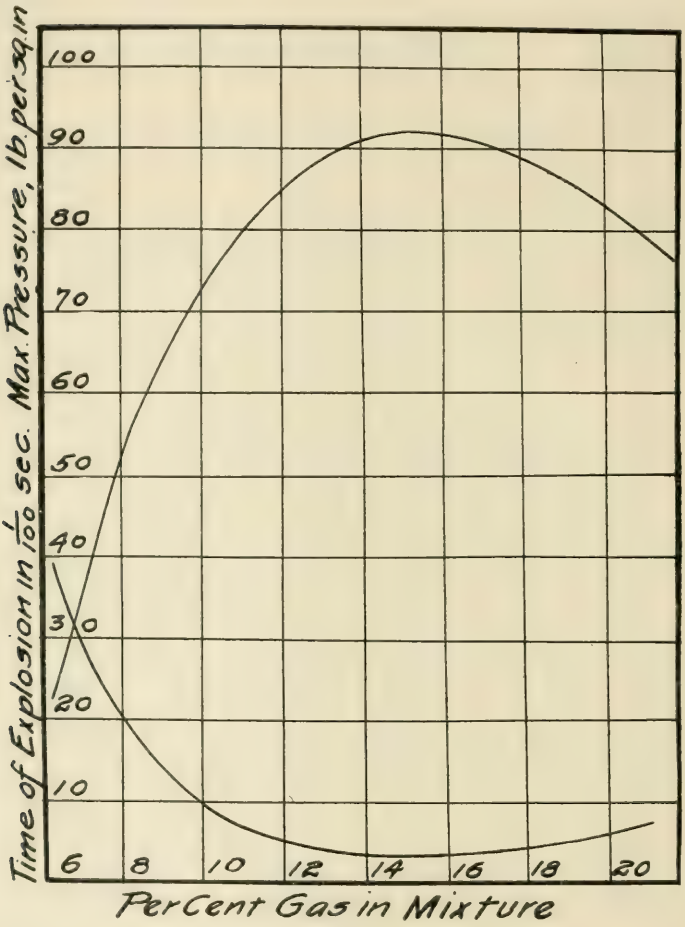


FIG. 3.—CURVES FOR BOSTON CITY GAS AND AIR.

of the dilution that in some explosions the pressure continued to rise for a second. In cooling, the dilution retards the rate, due to the long drawn out combustion of the gases. In general it seems that the higher the initial temperature the more readily the mixture is ignited and the faster will the combustion take place. Therefore the cooling water from the jacket of an engine should not be too cool.

From all of Mr. Allen's data the conclusions may be drawn that the best mixture for gasoline and air is about 10 or 11 to one by

weight. It is noticeable that the maximum pressure obtained from the mixture is not by any means proportional to the amount of gasoline in the cylinder. For instance, in the mixture of five to one, the pressure was not nearly so great as with eleven to one. Moreover the eleven to one gives good pressures with dilution. The effect of dilution is very important since all engines operate with some clearance space which has the effect of diluting the mixture. However, as the initial pressure or the compression increases, the effect of the dilution decreases.

EDGE HILL GRAVITY YARD.

By Theo. H. Trams, '07, Civil Engineering.

Within the last ten years the different railroads have been doing a great deal toward the betterment of their yards, because they have begun to realize the importance that a large yard has in a railroad system. Since the roads have realized the importance of a well designed yard most of them have been sparing no expense in order to so build all important yards that the maximum number of cars may be handled in a minimum amount of time and least amount of expense. Usually the attempt is made to so design a yard that as few engines shall be required to do the switching as possible, and to bring this about, the gravity type of yard has been the one usually adopted. All the later yards have been modeled more or less after the gravity yard at Edge Hill, England, this being the oldest and best known gravity yard.

The Edge Hill Yard is located near Liverpool, England, on the London and Northwestern Railroad. All trains arriving at Liverpool are broken up at Edge Hill, and all trains leaving Liverpool are made up at the same place. A gravity yard was suggested by the character of the ground on which the yard is located. The surface has a gradual rise from west to east, so tracks could be laid on a uniform grade at small cost.

For the economic operation two conditions seemed essential: first, that all changes necessary in the relative positions of the cars must be made between the summit and the foot of the incline without the assistance of locomotives. To meet the first condition the yard was divided into the following parts: First, the upper reception yard of six tracks, having a capacity of 264 cars. Second, the sorting yard comprising 24 tracks with a capacity of 1066 cars, into which the cars first run, each siding receiving the cars for a particular train. Third, two small groups of marshaling sidings through which the cars pass to be arranged into proper station order on their way to the fourth or departure yard. Fourth, the departure yard having a capacity of 183 cars or four trains. The second condition, requiring that some arrangement be devised for stopping cars, was met by the use of the chain drag, which consists of a heavy flexible

cable placed in a wrought iron tank below and between the rails. A steel hook connected to the cable is held by means of a loose socket in such a position that it will catch on the axle of any passing car, unless the socket and hook are lowered by means of a lever arranged for this purpose, before the car reaches the hook. When the car gets beyond the control of the shunters, the socket is left in its normal position and the hook catches on the axle of the passing car and drags the cable out of the tank and over the loose ballast until friction stops the car. The car is hauled back to its starting point by an engine, and the cable is allowed to drag back to its original position when it is unhooked from the car axle and placed in position for use when again needed.

The gradient of the track varies from 46 to 88 feet per mile, being greatest at the lower end of the reception, sorting, and gridiron sidings. The gradients are such that the greatest moving force is provided where the cars are required to start quickly and also where they must encounter the most resistance. All curves in this yard have a 462 foot radius.

The method of operation is as follows: All trains of cars on arrival in the yards proceed directly to the upper reception yard, where the engine is detached from the train, and the cars are inspected and each car is marked with the same number as that of the track to which it is to go in the sorting yard. The brakes on the cars are then released and they are dropped by gravity into the sorting yard. From the sorting yard the cars pass through the gridiron yards, where the cars are arranged in station order, into the departure yard.

The maximum number of cars passing through the yard in 24 hours is about 3000, which number can be increased to 5000 or 6000 cars with a small increase of sorting sidings. To handle the maximum number of cars requires about 75 men, the majority of these working only from 1 to 9 P. M., as the bulk of the work comes from 5 to 9 P. M.

EDITORIALS

The board offers this number of the TECHNOGRAPH as a publication that represents, in a measure, the work done in the College of Engineering, not alone that of the faculty and professors, but especially of students and undergraduates. We announce with pleasure that the contributions received from alumni came without solicitation. It has been the object of the board to secure such articles as would be of interest to all students in all of the departments. Some of the material is of purely local interest; we trust, however, that some of the included articles will be of real value to the practicing engineer. If this proves to be the case the contributors will feel more than repaid, and our thanks to the authors will be superfluous. Our thanks are also due to the members of the advisory board, who by their hearty co-operation and untiring efforts have made this publication possible.

More than ten years ago the Engineering societies formed an association for the purpose of mutual benefit. The object of this association was to give the engineering societies an opportunity to cooperate in their efforts to advance the interests of the engineering students; also to promote the science of engineering. To accomplish this latter purpose the TECHNOGRAPH, then in the tenth year of its existence, was issued by the association of engineering societies. At that time considerable interest was manifested in the association, but this has subsided more or less in late years. The societies clearly directed their activities to further their own interest, and at present considerable rivalry exists. This feeling of rivalry might be turned to good account. Each society should see that its own department was well represented in the TECHNOGRAPH. Every event of interest should be mentioned in this publication. The societies should require their representatives to report from time to time the

progress of the work of the TECHNOGRAPH board. In this way an active interest would be aroused which could only result in a better and a more representative publication. The societies should not forget that the record of their work is most effectively *handed down* through these pages. During the past year the electrical engineering society has had a remarkably successful "E. E. Show," but no record of it appears in this issue. The readers of the TECHNOGRAPH may doubtless look forward to a complete account next year, when the society finds time to take the matter up.

A very important step has been taken this year by some of the societies in supporting the TECHNOGRAPH. The Civil Engineers' Club in revising its constitution inserted a clause which states that every member in good standing shall receive a TECHNOGRAPH. The treasurer of the society then pays the TECHNOGRAPH board for the total number of copies received. This puts the business of the association of engineering societies on a firmer basis. A close estimate can be made of the probable sale and the publication can then be printed accordingly. Nearly everyone knows that the expense of publication can be varied greatly; tables printed on tip-ins, half tones and large cuts all go to increasing the cost, as well as making a better publication. Heretofore the board often times became involved in financial difficulties. The cause in nearly every instance could be traced to the fact that the estimated income was placed too high and consequently the actual sale was not large enough to meet the expense of publication. A few of the other societies are following the lead of the Civil Engineers' Club, and doubtless before another year all of the members of the association of engineering societies will adopt the same plan.

THE ENGINEERING SOCIETIES AND THE UNIVERSITY.

The present year has been a very successful one for the Mechanical Engineering Society. The membership has far surpassed that of former years and many progressive steps have been made. At the first meeting of the year, seventy-seven new members were voted into the society.

This year the society gave its first smoker. The evening was spent in telling yarns and listening to short talks by several members of the Engineering faculty. There was plenty to eat, drink and smoke in the way of cider, gingerbread and cigars. The smoker did much towards increasing the acquaintances and in furthering the spirit of fellowship among the members of the society. The society was very much pleased with the results of their first smoker and spirit shown by its members, so it was decided to make the smoker an annual affair.

The numbers of this year's lecture course are many and excellent. Professor Breckenridge, at the head of the Mechanical Engineering Department, opened the lecture course with a talk on the subject, "Mechanical Engineering." The series of lectures includes the following talks by faculty members: "Tool Steel and Tool Steel Work," by Prof. Gill; "The Engineer as a Man," by Prof. Thorpe; "Illinois Coals," by Prof. Parr; "The Constant Pressure Generator," by Mr. Garland; "Compressed Air Tools," by Prof. Schmidt; and "Steam Turbines," by Prof. Thorpe. The list of prominent speakers widely known in their particular lines of work is: Mr. A. Bement, a Consulting Engineer of Chicago; Mr. A. A. Brown, of the Westinghouse Machine Co.; Mr. B. A. Gayman, Asst. Chief Engineer of the Link Belt Co.; Prof. Frenald, of Washington University; and Mr. Wilson, of the Worthington Pump Co.

In addition to the meetings held for lecture course numbers, additional meetings of an informal nature are held at these additional meetings. Two or three members lead discussions along lines in which they have had some practical experience.

The annual inspection trip of the Senior class in Mechanical Engineering was taken the fourth week of last November. Most of the men went to Chicago on Saturday in order to see the Illinois-

Chicago football game. On Monday morning, at 8 o'clock, fifty-three Seniors reported to Messrs. Thorp, Lentwiler and Gill for the official opening of the inspection. The headquarters of the party were the Victoria Hotel in Chicago and the Plankinton in Milwaukee.

On the first day the South Chicago Works of the Illinois Steel Company and the power plants of several large office buildings were visited. Tuesday the party inspected the Fisk St. Station of the Chicago-Edison Company and the power plant of the South Side Elevated. Wednesday and Thursday were spent in Milwaukee visiting points of interest. The trip from Chicago to Milwaukee and back was made by boat at night so as to save time. Friday and part of Saturday the party spent in Chicago, the Western Electric being one of the most important plants visited.

A pleasant feature of the trip was the Alumni reunion dinner held at the Victoria Friday night. Here the undergraduates were given a chance to meet some of our best known and most prominent alumni. On Saturday noon ended what was declared the most successful inspection trip ever taken by the Mechanical Engineering Department.

This year's work of the Civil Engineers' Club has been characterized not only by live student interest in the proceedings of the Club, but also by an active, personal participation in the same. As a result the Club has retained its position as the largest student body of its class at this institution, and its meetings have been replete with interest and instructive experience. Student members spoke of their experiences in railroad location, construction and maintenance in the various parts of the United States and Mexico, railroad yards, concrete construction and inspection, drainage and irrigation works, river and harbor work, state highway construction, structural work, and office work and management. These talks were valuable not only in the knowledge gained therefrom, but also from the training accruing to the members from the subsequent discussions. At various times the Club has invited the corps of instruction and practicing engineers to deliver addresses. Many of these lectures were of a sufficiently general character as to be of interest in other colleges. Among the speakers were:

Prof. I. O. Baker, "The Civil Engineers' Club," "Why the United States Leads in Bridge Building," and "Summer Employment:" Mr. Roy H. Slocum, "Improvements of Mt. Vernon (Ind.) Waterworks;" Mr. G. H. Bremmer, Engr. Maintenance of Way, C. B. & Q. R. R., "The Duties of the Division Engineer;" Mr. O. E. Strehlow, '96, "Construction of Reinforced Concrete Bridges;" Mr. E. J. Mehren, '06, "The Construction of the New Pacific Extension of the C. M. and St. P. R. R.;" Prof. J. R. Brooks, "The Adjustment of Errors in Traverse Surveys;" Prof. F. O. Dufour, "Production of Pig Iron," "Steel Work;" Dean J. M. White, 'Student Life in Paris;" W. H. Radcliffe, '01, "Bridge Erection;" Mr. John W. Alvord, "Gary, the New Steel Town;" Mr. R. L. Humphrey, "The Effect of the San Francisco Earthquake Upon Building Material;" Mr. T. L. Condron, "Reinforced Concrete in Construction of Buildings;" S. T. Henry, '04, "Local Transportation Problems in New York City;" Mr. A. W. Newton, Inspector of Maintenance Department of C., B. & Q. R. R., "Field Work;" and Mr. W. D. Taylor, Chief Engineer of C. & A. R. R., "The College Man and the Engineer."

An important innovation is the holding of receptions in honor of the invited speakers. At these informal gatherings students have an opportunity to meet men prominent in the engineering world.

The principal event of the social side of Civil Engineers' Club was the first annual smoker open to all civil engineers in the University. Music, song, and smoke-talk furnished the gayety for the occasion, while tobacco, cider, apples, and doughnuts were the refreshments. Some two hundred guests and members were present.

The Senior class of Civil Engineers made their annual inspection tour to Chicago on April 17. The itinerary for the trip included the inspection of the Chicago river bridges from Rush to Kenzie streets, and several elevated railroads; a trip to Montgomery Ward & Company's reinforced concrete warehouse in process of erection, to the construction of a plain concrete retaining wall, and also to the C., B. & Q. R. R.'s work on reinforced retaining walls; an inspection of the Illinois Steel Co.'s South Works, and of the Lassig Bridge Plant; and, through the courtesy of Mr. W. A. Shaw, City Engineer, a trip in a tug to the in-take cribs and to the bridges along

the south branch of the Chicago river. The party returned April 21.

The corps of instruction of the Department of Civil Engineering has been materially strengthened by the acquisition of Messrs. Brooks, Slippy and Wiley.

Mr. John Pascal Brooks, M. S., associate member of the American Society of Engineers, Assistant Professor of Civil Engineering, was graduated from Dartmouth, class of '85. From 1886-'88 he engaged in railroad work and from 1888-'90 in municipal work. For seven years he taught civil engineering at Lehigh, which position he resigned for the professorship of civil engineering in Kentucky State College, where he remained until 1906. Prof. Brooks is joint author with Prof. Mansfield Merriman, of "A Handbook for Surveyors," and author of "A Handbook of Street Railway Location."

Mr. Ralph Bethnel Slippy, C. E., member of the Iowa Society of Engineers, Instructor of Civil Engineering, took his B. S. degree at Cornell College in 1903. Since that time, with the exception of a few months' teaching at Armour Institute, he has been actively engaged in railroad and municipal engineering. He has been connected with the engineering corps of the I. C., the C., B. & Q., and the W. & C. F. N. railroads.

Mr. Carroll Carson Wiley, University of Illinois, '04, is Instructor in Civil Engineering. Since graduation he has followed drafting work in Cincinnati and in Johnstown, Pa., and bridge drafting in Chicago.

At the spring election the following men have been elected to membership in Tau Beta Pi: H. L. Bushnell, A. S. Buyers, R. J. Candor, S. G. Cutler, R. E. Deets, H. E. Gonnerman, H. L. Hazard, E. B. Jordan, R. J. Love, L. McDonald, M. S. Morgan, G. E. Munger, R. C. Pierce, J. L. Stair, F. VanInwagen, E. A. Weber. Tau Beta Pi is an honorary fraternity, consisting of chapters established at most of the leading technical schools of this country. Its object is to mark in a fitting manner those men who have conferred honor upon their alma mater by a high grade of scholarship as undergraduates, or by their attainments as alumni. Although good scholarship is essential to membership in this society it is only the

first requirement. A candidate must not only be a good student, but he must possess those qualities which mark a man as a man among men, and which are indicative of a true gentlemen. The local chapter selects twenty-five men each year from the highest quarter of the class of engineers. In ascertaining a man's standing most weight is given to the junior grades, less to the sophomore and least to the freshmen. A student who continues to do better work as he advances in his college course is considered stronger and better fitted for the responsibilities of life than the student who stands out well in his freshman year and gradually declines in his studies as he approaches graduation.

The Architectural Club has been fortunate in hearing several interesting addresses from members of the faculty and other members of the profession.

On January 26, Prof. John W. Case spoke on "Colored Terra Cotta." He gave a description of the process of manufacture of enamelled terra cotta and its use in the decoration of Italian buildings; also a short history of the della Robbea family, who developed the ornamental use of burnt clay to a great extent.

Mr. Burt A. Lewis, of the office of Holabird & Roche, of Chicago, spoke to the club February 3 on "Building Superintendence in Chicago." Mr. Lewis' talk dealt largely with the construction of the new Cook County Court House. A number of photographs of the work at various stages were shown by means of the reflectoscope.

Mr. Benjamin E. Winslow, the noted Chicago architect and engineer, read a paper before the club March 1 on "Structural Design of Ordinary Buildings." This paper, together with the tables and charts shown in connection with it, appears elsewhere in this issue.

On April 4 a lecture was given by Mr. Peter B. Wight, of Chicago, secretary of the State Board of Examining Architects, on "Clay Products Used in the Fire Proofing of Buildings." Mr. Wight is a pioneer in the use of terra cotta in fire-proof construction in the United States and has devoted a great deal of study to the subject. He gave first a short history of terra cotta as used for fire-proofing, followed by a description of its manufacture and a discussion of its qualities. He then described several of the most

important systems of terra cotta construction and structure protection, illustrating with diagrams and photographs thrown on the screen by the stereopticon.

On the same evening Professor A. N. Talbot, of the Department of Theoretical and Applied Mechanics, gave a short talk on "Recent Tests of Hollow Tile Piers and Columns." These tests were made under Prof. Talbot's direction in the University Testing Laboratory and showed gratifying results.

The illustration of lectures has been greatly facilitated by the use of the new reflectoscope recently installed in the architectural lecture room. This instrument does not require the use of transparent slides, but projects perfectly any small illustration, whether drawing, print or photograph, black-and-white or in color, and so has a much wider range of usefulness than the stereopticon.

The first annual banquet of the Architectural Club was held at the Beardsley Hotel on Wednesday evening, April 3. The idea proved popular, and about fifty members were present. The menu, under the heading, "Specifications," was cleverly announced in architectural language and the cards were enclosed in artistic etched and hand-colored covers designed by M. B. Cleveland. Messrs. Peter B. Wight, of Chicago, and H. B. Wheelock, of Evanston, were guests of the club. The affair was marked by the pleasantest of good-fellowship and was thoroughly enjoyed by those present. The toasts, for the most part, were responded to in a jocular vein rather than handled seriously. The program of toasts was as follows: "Architecture," Toastmaster, Prof. N. C. Ricker; "Utility," Dean James M. White; "Beauty," Prof. Newton A. Wells; "Durability," Mr. Peter B. Wight; "License," Mr. H. B. Wheelock; "The Professor," Pres. M. B. Cleveland; "The Draftsman," L. J. McCarty; "Mischief," Fritz Wagner, Jr.; "Our Future," L. D. Howell.

The Architectural Club will be represented at the convention of the Architectural League of America at Washington, April 22, 23 and 24 by Prof. Newton A. Wells, chairman of the Committee on Education, and L. D. Howell, who will be the club's delegate. This club is the only one connected with a school of architecture that holds membership in the League.

The Architectural Club is now preparing a small annual w will show specimens of the work done by members of the club ing the last year. The illustrations will be printed from etc plates made by the students. Some of these will be water-colo by hand. The presswork will be done on the press owned by department, so that the entire work of producing the book will done by the members of the club. The annual will be a unique a beautiful souvenir as well as an index of the work done by the partment.

Professor Breckenridge's appointment as a member of the co mission to test turbine unit No. 8 of the Commonwealth Electi Co. was very fortunate for the Senior Mechanical Engineers. being allowed to participate in the work it gave them an opportu ty to do commercial testing before graduation. Furthermore th became acquainted with the methods of operating one of the large power plants in this country. The work was under the dire charge of Asst. Prof. Thorpe, to whom the seniors owe man thanks for the enjoyable time spent at the Fisk Street Station Those who took part in the test were: M. A. Kendal, J. A. Strawn E. D. Stearns, E. O. Jacob, F. M. Welch, L. C. Moore, F. E. Ervin A. H. Gunn, F. E. Hanke, J. M. Harnit, J. H. Hinman, R. D. Jessup, M. L. Millspaugh and Alwin Schaller.

The annual dinner of the Mechanical Engineering Seniors was held at the Columbia Hotel on April 6, '07. The menu cards were made up in class colors of red and white, with the University seal showing through the front cover. Nearly all of the seniors and M. E. faculty were present. E. O. Jacob acted as toastmaster and the following toasts were responded to: "Yale, Lehigh, Michigan, Illnois," Prof. Breckenridge; "Naught Seven," Prof. Goodenough; "Shop Talk," Prof. Gill; "Those Profs." M. A. Kendall; "The Heir to the Hoorah," Prof. Lentwiler; "The Engineer," Dean J. M. White; "99.44 Per Cent. Pure," W. A. Lazear; "Commercialism in the Faculty," Prof. Thorpe. After the toasts several extemperaneous speeches were made, the subject of all of which was the coming senior-faculty baseball game.

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1906—'08

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FOREWORD.

IN publishing the Technograph, the attempt has always been made to rise somewhat above the general college periodical, into a sphere which may contain some interest for the graduate, or the practicing engineer. We present in this issue some material which we think worthy of notice, both from its practical value, and from the fact that it shows to what an efficient point our facilities for research have been raised.

We wish to urge all those interested in the Technograph to pay due heed to our plans for next year, and, if such a change as is proposed is consumated, to give all possible assistance to the project.

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TO W. F. M. GOSS, DOC. ENG'G.,
DEAN OF THE COLLEGE OF ENGINEERING,
UNIVERSITY OF ILLINOIS,
THIS VOLUME OF THE TECHNOGRAPH
IS RESPECTFULLY DEDICATED.

DOC. W. F. M. GOSS.

THE TECHNOGRAPH

No. 22 UNIVERSITY OF ILLINOIS 1907-1908

AT THE HEAD OF THE FASTEST TRAIN IN PRUSSIA.

W. F. M. Goss, Doc. Eng'g.

It was still early on an October morning in Berlin when we began our inspection of the locomotive upon which we were to ride 102 miles to the City of Halle. The train to which it was coupled was made up chiefly of through cars. There were 40 axles carrying approximately 8 tons each, thus making the total weight of the train 320 tons. The locomotive, No. 605, was nearly new, and no exhibition engine ever appeared to better advantage. We admired its proportions and the quality of its finish, and I found a secret pleasure in noticing that in its wheel arrangement, this German machine was of the American type, but there was little else about it which could be credited to America, for No. 605 is a thorough foreigner. While to the casual observer it appeared to be a normal, single-expansion, eight-wheeled locomotive having piston valves actuated by Walschaert valve gears and drive wheels of large diameter, the practiced eye of the engineer, following one detail after another, might soon discover in the form of a valve, a pipe, or a handhold, evidences that the hidden mechanism which characterized this machine was a representation of the most advanced practice and belonged to German locomotive design. It was explained to me that combined with its boiler is a superheater designed to raise the steam to a high temperature during its passage from the boiler to the cylinder, and I had to confess that if American enthusiasm bounded a little at the sight of the wheel arrangement, it was distinctly depressed by the reflection that in Prussia there has been worked out with consummate skill what really amounts to a new system of practice in the matter of locomotive design, and which as yet has not greatly interested either American designers or American users of locomotives.

The route from Berlin to Halle as the railroad runs is a way much traveled by passengers from the north in their journeys to the south of Germany, to Switzerland and to Italy. We leave at 8 o'clock and run the 102 miles without a stop in 110 minutes, arriving at 9:50. Another train follows, leaving Berlin at 8:10, and is 120 minutes on the road, arriving at 10:10. A third starts at 8:20 and is 137 minutes on the road. Still another leaves at 8:30, another at 9:00, and four others before noon. It was there-

fore as leaders in a stately procession that we of No. 605 were to ride. A minute before eight we were all on the foot-board ready for the start. "We" were first a tall, broad-shouldered, fine spirited German, a graduate of Aix-la-Chapelle, a Regierungs baumeister of the Prussian State Railway, and for this trip my official companion. Next in order of rank was a mutual friend, a representative of the Wilhelm Schmidt Company, the patentees of the superheater with which the locomotive is equipped, who by his courtesies on this and other occasions made me many times his debtor. The third member of the inspecting party was the American. Besides these, of course, were the engineer and fireman. But introductions are brief, the signal is given, with both hands the engineer pulls down on his throttle lever, which moves in a vertical plane, until it is more than half way open, and now that the engine is starting he gives the throttle no further attention, but stands with his hands on the reverse-wheel, watching the struggle of the locomotive for mastery over its train. When the drivers slip, he catches them with a quick turn of the reverse-wheel before they have made a single revolution. If they hold well, he slowly turns the reverse-wheel to lengthen the cut-off. Under similar conditions the engineer of an American locomotive would have had his hand upon the throttle lever, opening and closing it as the adhesion of the wheel might require, and if it were suggested to him that the throttle be left well open, and that the output of power be controlled by means of the reverse lever, he would probably smile and tell you that the reverse lever is too clumsy a device to serve in giving the delicate gradations of power needed. But here stands the German at a screw driven reverse gear, which has always been regarded by Americans as too slow and laborious for successful use, feeling with a sensitiveness of touch which is fine, the adhesion of drivers upon the rail, and with one hand and little effort holding his engine to the hardest work it is capable of doing. We are now moving out through the terminal yard, the speed of the train is steadily increasing, the danger of slipping wheels is passed, and the engineer is busy in perfecting adjustments which will bring all parts of the mechanism into condition of most efficient working. High up upon the side of the cab at his right is a speed indicator, which shows him at a glance the rate at which he is running. In front of him besides the usual boiler gage, is another gage which gives the pressure of steam in the valve-box. The maximum boiler pressure is 180 pounds, and it is explained that the purpose of the engineer is to keep the valve-box pressure approximately 150 pounds. As the speed increases, he adjusts by small increments, first the cut-off then the throttle until the output of power and the conditions of pressure are to his liking. Another dial before him is that of a thermometer indicating the temperature of the steam in the valve-

box. This at the instant of starting was but little above 400° F., but has since risen steadily. It is desirable that it should not go above 660° F. By the time we are at speed it has passed the 550 mark, and the engineer crossing over to the fireman's side turns a wheel attached to a light shaft running out forward over the boiler, thus partially closing the damper and thereby diminishing the flow of furnace gases through the superheater. These devices, the speed indicator, the gage to show the pressure of steam in the valve box, the thermometers indicating the temperature of steam in the valve box, a permanently attached draft gage not before referred to, and of course the hand wheel for adusting the superheater damper, are all in the nature of additions to the equipment common on American locomotives. By attention given to these several devices the engineer is able to operate his machine with a delicacy of adustment that insures high efficiency in action.

Our train is now well out of the city, moving forward over a well finished German landscape, past stations, through cities, always at a speed of from 55 to 65 miles an hour. The engineer stands at his post, generally keeping a lookout ahead, but occasionally moving about the cab that he may better scrutinize the adjustment of his machine. I had already admired his blue uniform, the military-looking cap, and the gilt locomotives on the lapels of his coat, when one of our party called my attention to his soldierly appearance and added, "He doesn't work; he's an officer." I can vouch for the fact that he is a skillful locomotive runner, and at the end of the run I learned to know him as a fine fellow. But I could not help wondering whether the average American locomotive runner would be willing to surrender the comforts of his perch on a cushioned box well up out of the way of the coal and dust on an American locomotive for official standing on a German foot-board. The fireman, also in blue, had swung into action soon after the start. At intervals varying from two to four minutes he fired from four to ten scoopfuls of a free burning mixture of fine coal and lumps. From the tenth to the fortieth minute of our run the average rate of firing was 2.8 scoopfuls a minute. Each time before putting in coal he shut off the injector, and after he had finished firing he started it again.

Thus the journey proceeded, the speed on favorable grade rising to 68 miles per hour and falling on adverse grade below 55. The track was always clear. At Wittenberg, we passed at a high rate of speed through a station crowded with people, and a little beyond, at the crossing of the Elbe, 63 miles from Berlin for the first time during the run the throttle was closed and the brakes applied for a slow at the bridge. The engineer of an American locomotive after closing the throttle must move the reverse lever to its extreme position on the quadrant in order that the compression

effects in the cylinders may be reduced; but our engineer does nothing of the sort. He allows his reverse gear to stand in running position, but pulls a handle which opens a valve in a by-pass connecting the two ends of the cylinder, and this open by-pass affords relief from the compression that would otherwise occur. Toward the close of our journey we were running ahead of our schedule and were several times required to slow on signal. notwithstanding which fact we were at Halle two minutes before we were due.

This run of 102 miles ended the day's work of our locomotive. We went with it as far as the cinder pit, from which point we saw the train which we had brought, proceed southward drawn by a fresh locomotive. From the cinder pit No. 605 was to go to the roundhouse, there to await a train for the return trip on the morrow.

THE ACCELERATION RESISTANCE AND KINETIC ENERGY, OF TYPICAL ELECTRIC CARS.

G. E. Jaquet, R. E. E., '08.

In General. In the operation of electric cars, the power developed by the motor equipment is absorbed by the action of several resisting forces, which we commonly refer to as resistances. These resistances are usually grouped under two heads—true train resistance and accidental resistance. The former comprises all the resisting forces, that act owing to the particular construction of the car itself, and all of which are always operative when the car is running. The group of resistances is made up of rolling friction, journal friction, flange friction, etc., which are lumped into one factor, designated as true train resistance. The accidental resistances, comprise grade resistance, curve resistance, wind resistance and acceleration resistance, any or all of which may or may not be operative at any given instant, depending on the schedule to be maintained, profile of road, and weather conditions. The last named factor—acceleration resistance—is an exceedingly important one, as it determines to a large extent, the capacity of the motors to be used for a given schedule.

The element of acceleration resistance occurs most frequently in two general types of traction problems. One is the problem of selecting the requisite motor equipment for maintaining a certain schedule with a car of given weight. The solution of this problem depends on the determination of the total tractive effort required to give the car, the acceleration called for by the schedule. The greater part of this tractive effort is made up of acceleration resistance or tractive effort due to acceleration, and hence it is of considerable importance to have available, accurate values of acceleration resistance for the car in question. The second problem which often presents itself, in traction work, is that of determining the average acceleration of a car in actual operation, from a graphical speed record, taken during the run. Where the acceleration has been uniform over a given section of track, its value can be obtained from the slope of the speed curve. More often, however, it is the case that the acceleration has varied considerably over a given section of the run, and the value of the average acceleration over that section, is desired. This is obtained from the relation.

$$\text{Acceleration} = \text{Constant} \times \frac{\text{Change in kinetic energy, over section.}}{\text{Total equivalent weight of car} \times \text{length of section.}}$$

The change in the kinetic energy over section, is the difference in kinetic energy of car at beginning and end of section, respectively. For a given car, the kinetic energy will vary as the square of speed.

Knowing the speed at beginning of section and at exit, the kinetic energy on entering and leaving the section respectively, can be calculated. When accurately determined values of kinetic energy for different types of cars, are available, this process of calculation can be dispensed with and the rapid solution of this class of problems be greatly assisted.

The general equation for acceleration resistance, commonly used is,

$$R = 91.1\ W\ A \qquad (1)$$

in which

W = Weight of car in tons.

A = acceleration in miles per hour per second; also the general equation for kinetic energy for a moving car is,

$$E = 66.76\ W\ V^2 \qquad (2)$$

in which

V = speed in miles per hour.

Effect of Rotating Parts.

The two equations, given above, which find very general use, in calculations such as have been outlined, do not take into account the presence of the rotating parts,—wheels, axles, and armatures—that form part of the car. These two equations—(1) and (2)—and calculations involving acceleration resistance or kinetic energy are based on the assumption that only motion of translation takes place. The neglect of the presence of rotating parts leads to an error ranging from five to nine per cent in the case of acceleration resistance and to an even larger percentage of error in the case of kinetic energy calculations. The general impression that the effect of the presence of rotating parts is so small as to be negligible, is probably responsible largely for the general practice of neglecting it. Some engineers, however, realize its magnitude and make due provision for it. One method frequently employed, is to increase the value of the acceleration factor—91.1—in the formula for acceleration resistance—$R = 91.1\ W\ A$—by an amount, corresponding to the inertia effect of the rotating parts. The value of this corrected factor of acceleration resistance has been determined by the writer for several types of cars and is given in column A, Table III, page 15. Another method used, is that of increasing the dead weight of car, by an amount corresponding to the effect of the rotating parts. The value of this equivalent weight has also been determined by the writer for different cars and is given in column B, Table III, page 15.

In order to take into account the effect of the presence of rotating parts in the fundamental equation (1).

$$R = 91.1\ W\ A,$$

we must modify it by adding the component due to the presence of

the rotating parts. This latter component can be expressed in the form C A, where C is a constant, that depends on the inertia of rotating parts. Hence the modified form of equation (1) will be

$$R = 91.1\ W\ A + C\ A. \qquad (3)$$

For a given car, the weight (W) will be constant and we can represent the quantity 91.1 W by a constant, which we will call K_1. Also the constant C will have a particular value, for this car, which we will call K_2. Hence equation (3) will become

$$R = R_1 + R_2 = K_1\ A + K_2\ A$$

in which

$R_1 = K_1\ A$ = Resistance due to translation of car.

$R_2 = K_2\ A$ = Acceleration Resistance due to rotation of revolving parts.

The constants K_1 and K_2 can be combined in one, which we will designate as K, and we have

$$R = K\ A$$

where K A = Resistance due to translation of car and rotation of revolving parts.

The method of allowing for presence of rotating parts, outlined above, applies in a similar way to the general equation for kinetic energy,

$$E = 66.76\ W\ V^2 \qquad (1)$$

In this case, the component due to presence of rotating parts may be given the form $C^1\ V^2$. So we have for the modified form of equation 1,

$$E = 66.76\ W\ V^2 + C^1\ V^2.$$

For a given car, it can be expressed in the form

$$E = \underbrace{B_1\ V^2}_{\text{Translation}} + \underbrace{B_2\ V^2}_{\text{Rotation}} = E_1 + E_2$$

in which

$E_1 = B_1\ V^2$ = Kinetic energy due to translation of car.

$E_2 = B_2\ V^2$ = Kinetic energy due to rotation of revolving parts.

Adding the two constants B_1 and B_2, and designating their sum by B, we have for the final form of the energy equation,

$$E = B\ V^2$$

where $B = B_1 + B_2$.

PURPOSE.

The purpose of this article is to present accurately determined values of acceleration resistance and kinetic energy, that include the effect of rotating parts, in such form, that the reader can determine readily the value of these qualities for different cars in service. To accomplish this result, the acceleration resistance and kinetic energy have been computed for seven different cars, each typical of the equipment used for a given class of service. To deter-

mine approximately, the acceleration resistance or kinetic energy of a particular car, the reader has only to refer to Tables I and II, pages 13 and 14, and obtain the values of the constants given for that particular type of car. All results are given in Table I, II and III, under head "Results."

The above data has been expressed graphically in the form of curves, which are given in the section entitled "Curves."

The general theory underlying the equations used and the expressions from which the values of the constants K_1, K_2 . . . B, were computed, is outlined briefly, under the head, "Derivation of Expressions for Acceleration Resistance and Kinetic Energy."

The manner in which the data submitted was calculated and the assumptions made are given under title "Calculation of Results."

RESULTS.

Acceleration Resistances and Kinetic Energy of Different Cars.

The results of the calculations made by the writer, are given in Tables I and II, pages 13 and 14. The values of the seven constants have been computed for five different cars, each representative of a different class of service. The cars, taken as a whole, it is believed, cover pretty thoroughly the range of equipment in use today.

Table I, page 13, shows the value of the constants K_1, K_2, and K for the determination of acceleration resistance. Each of these constants when multiplied by the acceleration of the car gives respectively, the resistance due to the translation of car, resistance due to rotation of revolving parts and the total resistance. The acceleration must be expressed in miles per hour per second and the resistance obtained will be in pounds.

Table II, page 14, shows the values of constants B_1, B_2, and B, for the determination of kinetic energy of an electric car. Each of these constants, when multiplied by the square of the velocity at which the car is traveling, will give respectively, the kinetic energy due to translation of car, the kinetic energy due to rotation of revolving parts, and the total kinetic energy of the moving car. The velocity must be expressed in miles per hour and the kinetic energy will be given in foot pounds. These values have been determined for three conditions of loading, as the ratio of the rotative effect to the dead load will vary with the condition of loading.

Correction for Presence of Rotating Parts.

The results of the writer's investigations with reference to the effect of rotating parts on acceleration resistance are summarized in Table III, page 15. Column A gives the corrected value of the acceleration factor, which takes into account correctly the effect

TABLE I.

Acceleration Resistance of Different Types Electric Cars.

Value of the Constants K, K_1, K_2, in the Formula.

Acceleration Resistance = Constant × Acceleration.

$R = K A.$

Car Number*	TYPE OF CAR AND CLASS OF SERVICE.	Car Empty.				Car Loaded to Seating Capacity.				Car Loaded to Seating and Standing Capacity.			
		Acc. Res. of Rotation Values of K_2	Acc. Res. of Translation Values of K_1	Acc. Res. of Rotation and Translation Values of $K (= K_1 + K_2)$	Per Cent Rotational Effect.	Seating Capacity.	Acc. Res. of Translation Values of K_1	Acc. Res. of Rotation and Translation Values of $K (= K_1 + K_2)$	Per Cent Rotational Effect.	Combined Seating and Standing Capacity.	Acc. Res. of Rotation Values of K_2	Acc. Res. of Rotation and Translation Values of $K = K_1 + K_2$	Per Cent Rotational Effect.
		K_2	K_1	K	D	E	K_1	K	D	E	K_1	K	D
I	Light City Car, 2 Motors	73.4	902	975	7.5	33	1082	1155	6.3	55	1232	1305	5.6
II	Heavy City Car, 2 Motors	146.	1690	1836	7.8	46	2004	2150	6.8	96	2346	2492	5.9
III	Heavy City Car, 4 Motors	163.	1690	1853	8.8	46	2004	2167	7.5	96	2346	2509	6.5
IV	Light Interurban Car, 2 Motors	153.2	1690	1843	8.3	51	2038	2192	7.0	87	2284	2438	6.3
V	Light Interurban Car, 4 Motors	171.	1690	1861	9.2	51	2038	2210	7.8	87	2284	2456	7.0
VI	Heavy Interurban Car, 4 Motors	212.	2861	3073	6.9	54	3229	3441	6.0	111	3619	3831	5.5
VII	Very Heavy Interurban Car, 4 Motors	244.	4555	4799	5.1	55	4930	5174	4.7	130	5443	5687	4.3

*Roman Numerals refer to the Description of Cars, Pages 27, 29, 31, 33.

†Ratio $\frac{K_1}{K}$, expressed in per cent.

‡Weight of Passengers, based on 150 Pounds Per Passenger.

TABLE II.

KINETIC ENERGY OF DIFFERENT TYPES ELECTRIC CARS.

Values of the Constants B_1, B_2 and B in the Formula.

Kinetic Energy = Constant × Square of Velocity.

$E = K V^2$.

Car Number*	TYPE OF CAR AND CLASS OF SERVICE.	Car Empty.				Car Loaded to Seating Capacity.‡				Car Loaded to Seating and Standing Capacity.‡			
		Kinetic Energy of Rotation Values of K_1'	Kinetic Energy of Translation Values of K_1'	Kinetic Energy of Rotation and Translation Values of $K' = (K_1' + K_2')$	Per Cent Rotational Effect.†	Seating Capacity.	Kinetic Energy of Translation Values of K_1'	Kinetic Energy of Rotation and Translation Values of $K' = (K_1' + K_2')$	Per Cent Rotational Effect.†	Combined Seating and Standing Capacity.	Kinetic Energy of Translation Values of K_1'	Kinetic Energy of Rotation and Translation Values of $K' = K_1' + K_2'$	Per Cent Rotational Effect.†
		B_2	B_1	B	D	E	B_1	B	D	E	B_1	B	D
I	Light City Car, Single Truck, 2 Motors..	95.4	661	766	12.4	33	793	888	10.7	55	903	998	9.5
II	Heavy City Car, 2 Motors.....	157.	1238	1395	12.6	46	1469	1625	9.6	96	1719	1876	8.4
III	Heavy City Car, 4 Motors.....	196.	1238	1434	13.6	46	1469	1665	11.7	96	1719	1915	10.2
IV	Light Interurban Car, 2 Motors.....	130.	1238	1368	10.5	51	1494	1624	8.0	87	1674	1804	7.2
V	Light Interurban Car, 4 Motors.....	166.	1238	1405	11.8	51	1494	1660	10.0	87	1674	1840	9.0
VI	Heavy Interurban Car, 4 Motors.....	196.	2096	2292	8.5	54	2367	2566	7.6	111	2655	2851	6.8
VII	Very Heavy Interurban Car, 4 Motors..	239.	3338	3577	6.7	55	3613	3852	6.2	130	3986	4228	5.7

*Roman Numerals refer to the description of cars, Pages 27, 29, 31, 33.

†Ratio $\frac{K_1'}{K'}$, expressed in per cent.

‡Weight of Passengers based on 150 Pounds per Passenger.

of rotating parts. This factor, when only motion of translation is considered, has a value of 91.1 pounds and is the pull required to give a ton, an acceleration of one mile per hour per second. The value of the correction required to take into account the effect of rotating parts, is obtained from the relation

$$\text{Correction} = \frac{\text{Weight of car.}}{K_2}$$

The corrected value of the acceleration factor will be,

$$\text{Acceleration factor} = 91.1 + \text{correction.}$$

Column B, Table III, gives the equivalent weight, corresponding to the effect of the rotating parts. The effect of rotating parts is often taken into account by adding to the total weight of the car, this equivalent weight corresponding to the effect of rotating parts. The value of this equivalent weight is determined from the relation

$$\text{Equivalent weight} = \frac{K_2}{91.1}$$

TABLE III.

VALUES OF ACCELERATION FACTOR AND EQUIVALENT WEIGHT FOR DIFFERENT TYPES OF CARS.*

Car No.	DESCRIPTION OF CAR	Value of Constant in Equation R=KWA	Equivalent Weight due to Effect of Rotating Parts—Tons
		A	B
I	10-Ton Single Truck City Car, 2 Motors.....	97.9	.81
II	19-Ton Double Truck City Car, 2 Motors.....	98.4	1.61
III	19-Ton Double Truck City Car, 4 Motors....	99.2	1.79
IV	19-Ton Interurban Car, 2 Motors.....	98.6	1.68
V	19-Ton Interurban Car, 4 Motors.....	99.5	1.88
VI	31-Ton Interurban Car, 4 Motors.....	98.0	2.45
VII	50-Ton Interurban Car, 4 Motors.....	95.8	2.68

CURVES.

From the data given in Table I, the acceleration resistance of the different cars, for various values of acceleration has been computed. These results are embodied in a series of curves, Figures I to V inclusive. Figure I shows the variation in total acceleration resistance of the various cars, with acceleration. This set of curves

* Computed on basis of car loaded to seating capacity.

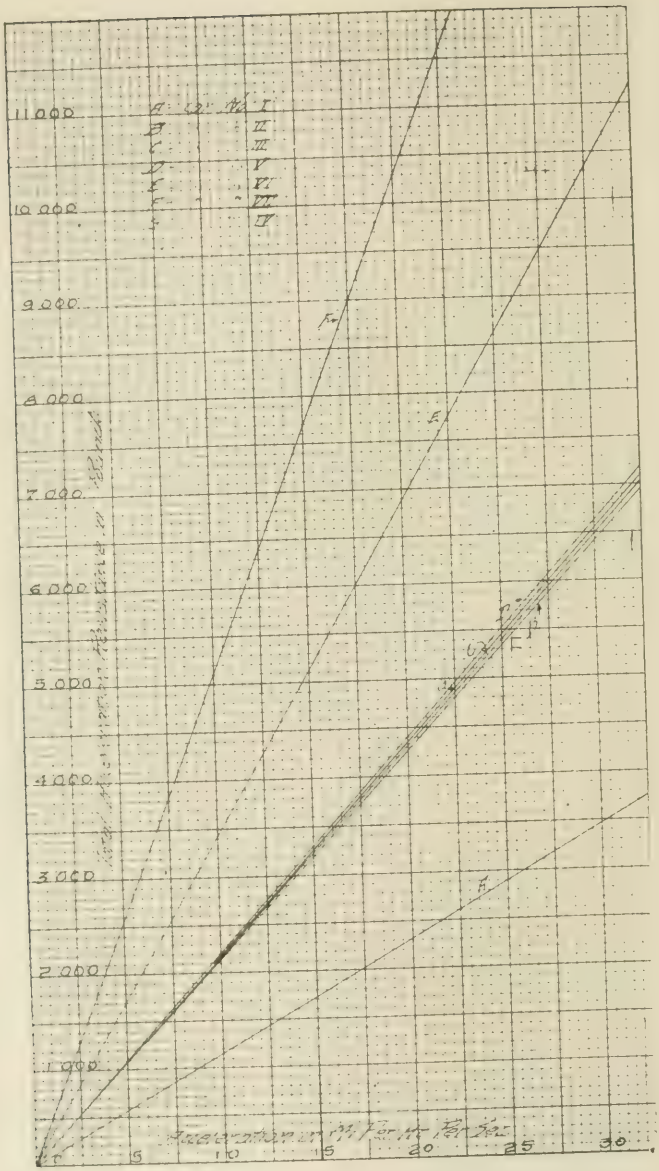


Fig. I. Acceleration Resistance—Different Types of Cars

was plotted on the basis that the car in each case is loaded to seating capacity. Figure II indicates the relative magnitude of the rotative effect of the revolving parts, in the different cars. Figures 3, 4, and 5 show the difference in acceleration resistance due to increased loading of car, for three types of cars.—Cars No. I, VI, and VII. The effect of loading is more marked than is usually supposed.

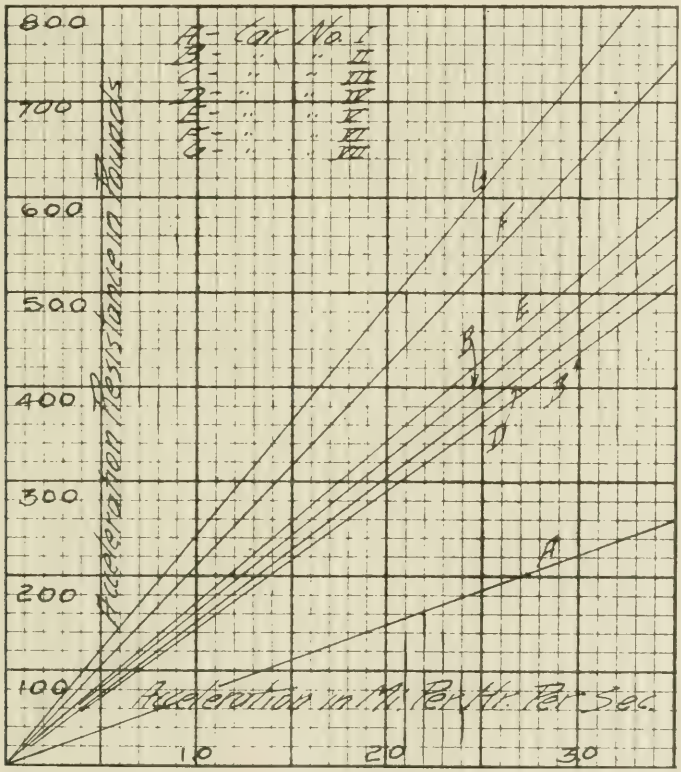


Fig. II. Acceleration Resistance Due to Rotation in Different Cars.

In a manner similar to the above, the kinetic energy of the different cars has been calculated from the data given in Table II, for various values of speed and the results expressed graphically, as in the case of acceleration resistance. Figure VI indicates the total kinetic energy of the different types of cars, for various speeds. The kinetic energy, it will be noted, varies directly as the square of the speed. Figure VII gives values of kinetic energy due to

rotation for the different types of cars and affords a ready comparison of the relative magnitude of this factor in the different types of cars.

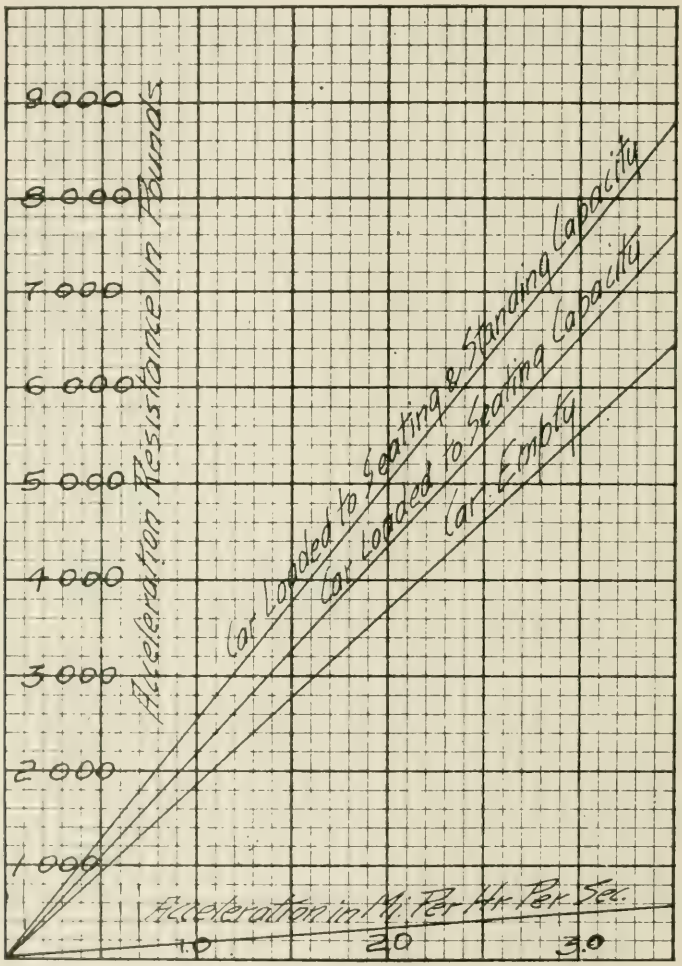


Fig. III. Acceleration Resistance—Car No. I.

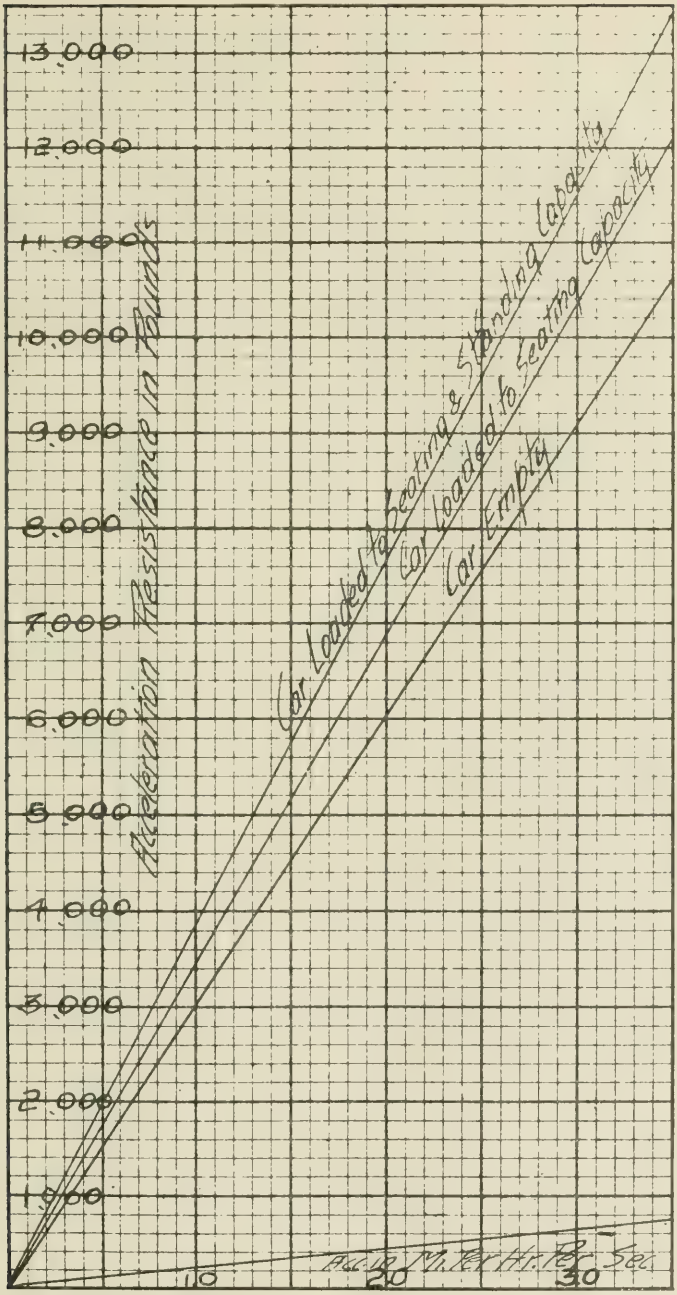


Fig. IV. Acceleration Resistance—Car No. VI.

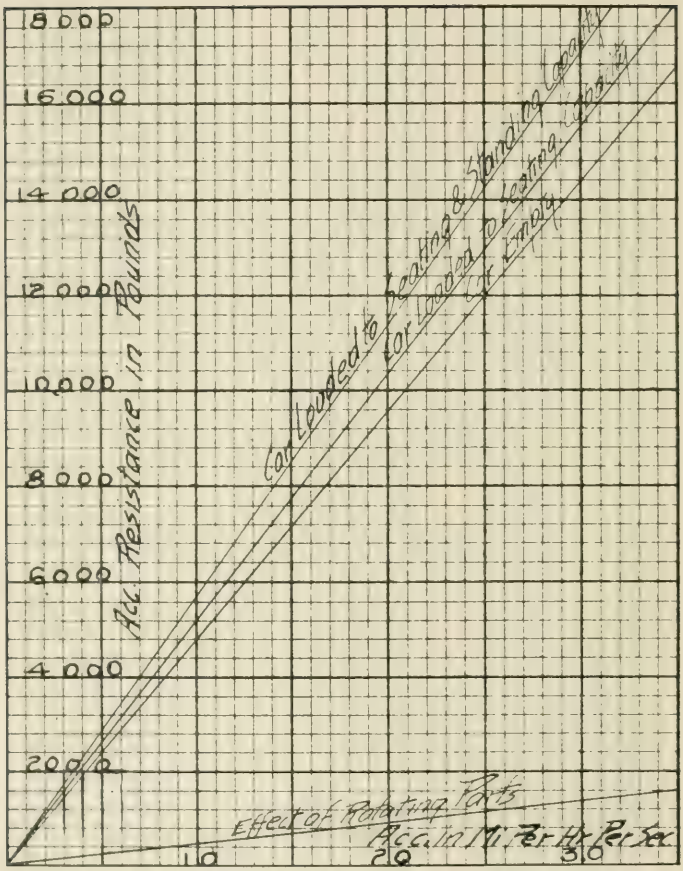


Fig. V. Acceleration Resistance—Car No. VII.

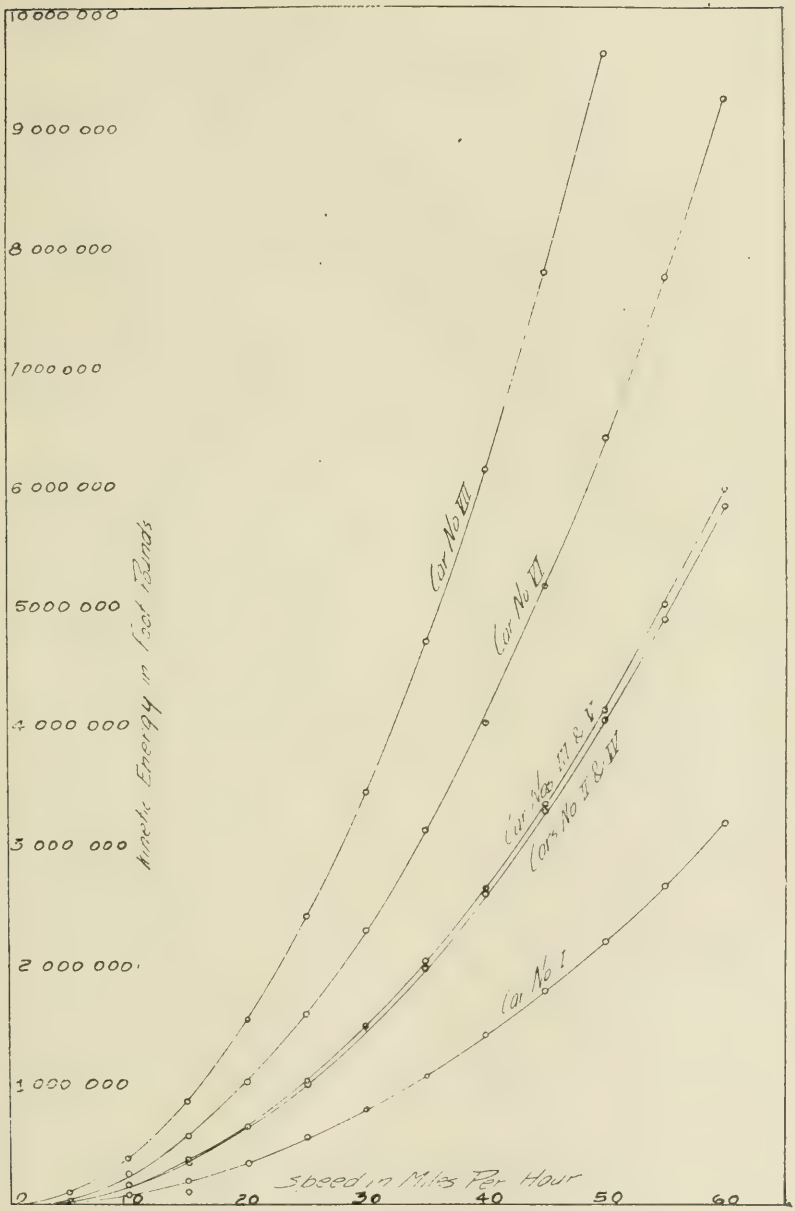


Fig. VI. Total Kinetic Energy—Different Types of Cars.

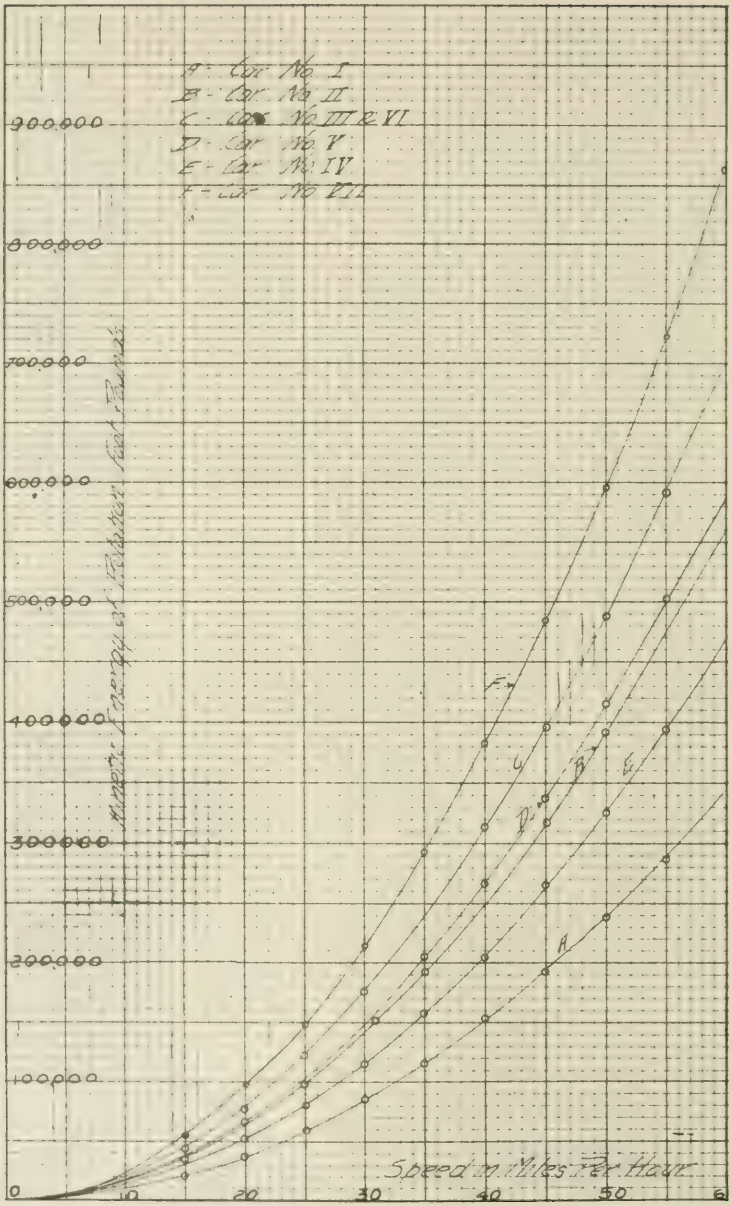


Fig. VII. Kinetic Energy Due to Rotation—Different Types of Cars.

DESCRIPTION OF CARS.

The cars considered in this article, were chosen with special reference to representing the different types of equipment in use. Seven cars were considered, representing five classes of service, as shown below:

Car No. I. Light city service.
Car No. II. Heavy city service, 2 motors.
Car No. III. Heavy city service, 4 motors.
Car No. IV. Light interurban service, 2 motors.
Car No. V. Light interurban service, 4 motors.
Car No. VI. Heavy interurban service.
Car No. VII. Very heavy interurban service.

The general dimensions for cars Nos. I to VI inclusive, were taken from the "Report of the Electric Railway Test Commission," published by the McGraw Publishing Co. They are the result of inquiries sent out by the commission to a large number of manufacturing firms and operating companies, asking for detailed information regarding the electric cars built or used by those firms and companies. This data is given in Tables III to VII inclusive, pages 24 to 32, under the caption "Dimensions of Typical Electric Cars." Those items marked by an asterisk were not obtained from the Report of the Railway Test Commission, but were kindly supplied by the St. Louis Car Company, St. Louis, Mo., at the request of the writer.

On the page facing the table of dimensions for each car, is shown a diagrammatic view of a car, in actual service, which approaches closely the car specified by the average data on the corresponding page. These views are reproduced from the "Street Railway Journal" and the "Report of the Electric Railway Commission" by permission of the publishers, McGraw Publishing Co.

There is one class of equipment in use to-day which is not represented by any of the cars described above. This is the very heavy type of electric cars, used for high speed service by several of the electric railways of the country. The "limited cars" operated to-day by the Fort Wayne and Wabash Valley Traction Co., between Indianapolis and Fort Wayne are very good examples of the best recent construction in this type of equipment. Hence this car has been taken as typical of the heavy high speed cars now in use and of those destined to be used for some time to come. Through the courtesy of Mr. E. C. Emmons, general manager, and Mr. L. W. Jacques, master mechanic, respectively, of the Fort Wayne and Wabash Valley Traction Co., the writer has secured the general data for this car. It is designated as Car No. VII in the tables and curves of this article. From the data obtained, the acceleration resistance and kinetic energy have been calculated and are given in Tables I and II.

TABLE IV.

Dimensions Typical Electric Cars.—Car No. 1.

SINGLE TRUCK CAR FOR LIGHT CITY SERVICE.

Average data compiled by Electric Railway Commission.

CAR BODY.

Length over all	29 ft., 6 in.	Weight equipped	8,400 lbs.
Length over platforms	3 ft., 11 in.	Capacity seating	33
Width over all	7 ft., 11 in.	Capacity standing	32

Weight of car complete ..... 18,800 lbs.

TRUCKS.

Weight	5,090 lbs.
Speed Rating	18.5 mi. per hr.
Wheel Base	6 ft., 6 in.
Diam. of Wheels	33 in.
*Weight Wheels	425 lbs.
Diam. Axles	4 in.
*Weight Axles	260 lbs.

MOTORS.

Number per car	2
Voltage	550 volts
Capacity each	37 horse power
Gear Ratio	4.455
Weight of Armature	549 lbs.
Diam.	14 in.
*Weight of Gear	220 lbs.

TABLE V.

Dimensions Typical Electric Cars—Cars No. II and III.

DOUBLE TRUCK CAR FOR HEAVY CITY SERVICE.

Average data compiled by Electric Railway Commission.

DOUBLE TRUCK CITY CAR, TWO MOTORS.—CAR NO. II.

CAR BODY.

Length over all	40 ft., 9¾ in.	Weight equipped	18,730 lbs.
Length over platforms	4 ft., 6⅞ in.	Capacity seating	40
Width over all	8 ft., 4½ in.	Capacity standing	50
Weight of car complete	37,100 lbs.		

TRUCKS.

Weight	5,790 lbs.
Speed Rating	20 mi. per hr.
Wheel Base	4 ft., 8 in.
Diam. Wheel	33 in.
*Weight Wheel	500 lbs.
Diam. Axles	4⅜ in.
*Weight Axles	350 lbs.

MOTORS.

Number per car	2
Voltage	500 volts
Capacity each	43 horse power
Gear Ratio	4.15
Weight of Armature	704 lbs.
Diam. of Armature	14 in.
*Weight of Gear	220 lbs.

DOUBLE TRUCK CITY CAR, FOUR MOTORS—CAR NO. III.

Car Body, Trucks and Weight of Car Complete, same as above.

MOTORS.

Number per car	4	Weight of Armature	552 lbs.
Voltage	550 volts	Diam. of Armature	14 in.
Capacity each	35 horse power	Weight of Gear	220 lbs.
Gear Ratio	4.26		

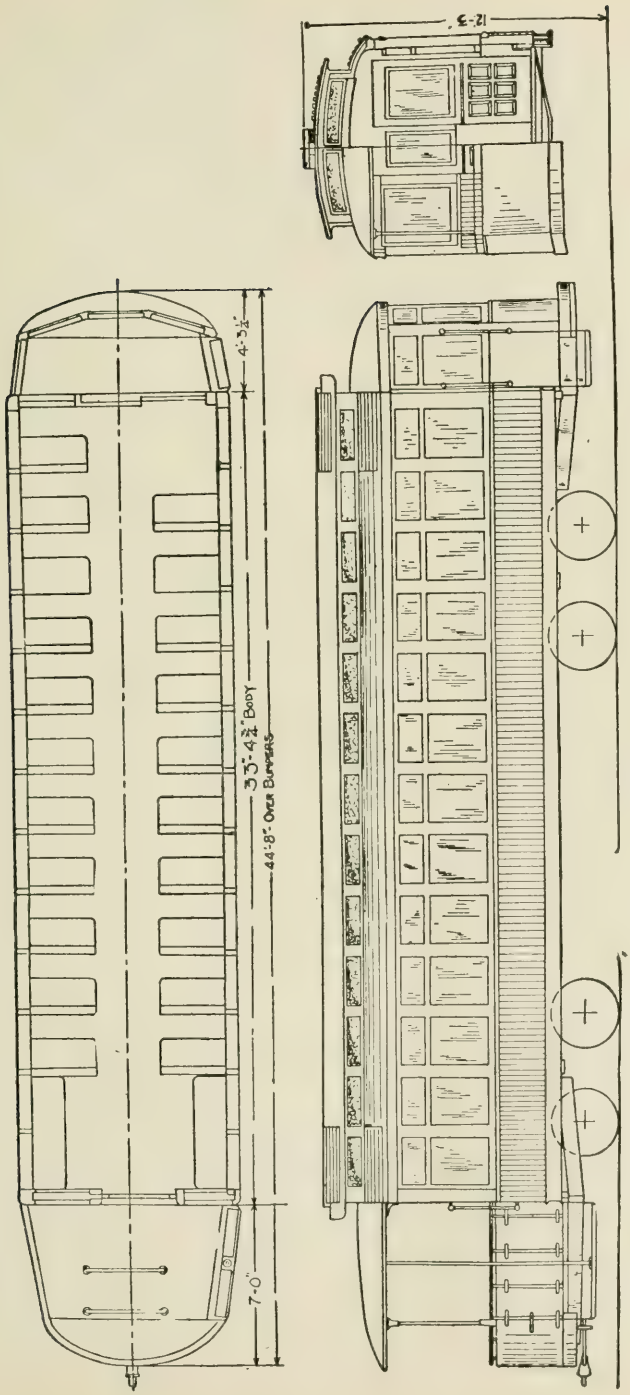


Figure 9. Typical Diagram of Double Truck Car for Heavy City Service.—Cars No. II and III.

TABLE VI.

Dimensions Typical Electric Cars—Cars No. IV and V.

INTERURBAN CAR FOR LIGHT SERVICE.

Average data compiled by Electric Railway Commission.

CAR WITH TWO MOTORS.— CAR NO. IV.

CAR BODY.

Length over all	41 ft., 2 in.	Weight equipped	19,230 lbs.
Length over platforms	4 ft., 10¾ in.	Capacity seating	51
Width over all	8 ft., 6 in.	Capacity standing	36
Weight of car complete	37,100 lbs.		

TRUCKS.

Weight	4,870 lbs.
Speed Rating	31 mi. per hr.
Wheel Base	4 ft., 6 in.
Diam. Wheel	33 in.
*Weight Wheel	550 lbs.
Diam. Axle	4 in.
*Weight	480 lbs.

MOTORS.

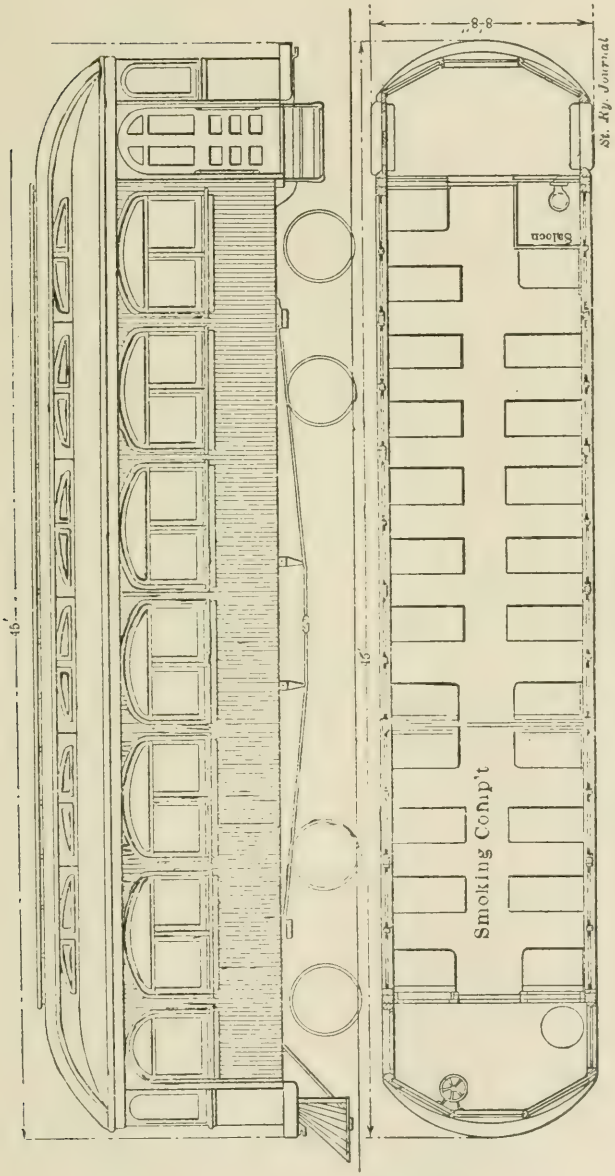
Number per car	2
Voltage	550 volts
Capacity each	45 horse power
Gear Ratio	2.877
Weight of Armature	666 lbs.
Diam. of Armature	14 in.
*Weight of Gear	265 lbs.

CAR WITH FOUR MOTORS.—CAR NO. V.

Car Body, Trucks, Axle and Weight of Car Complete, same as above.

MOTORS.

Number per car	4	Weight of Armature	592 lbs.
Voltage	550 volts	Diam. of Armature	14 in.
Capacity each	42 horse power	*Weight of Gear	265 lbs.
Gear Ratio	3.18		



KOKOMO, MARION & WESTERN CAR

Figure 10. Typical Diagram of Interurban Car for Light Service.—Cars No. IV and V.

TABLE VII.

Dimensions Typical Electric Cars.—Car No. VI.

INTERURBAN CAR—HEAVY SERVICE.

Average data compiled by Electric Railway Commission.

CAR BODY.

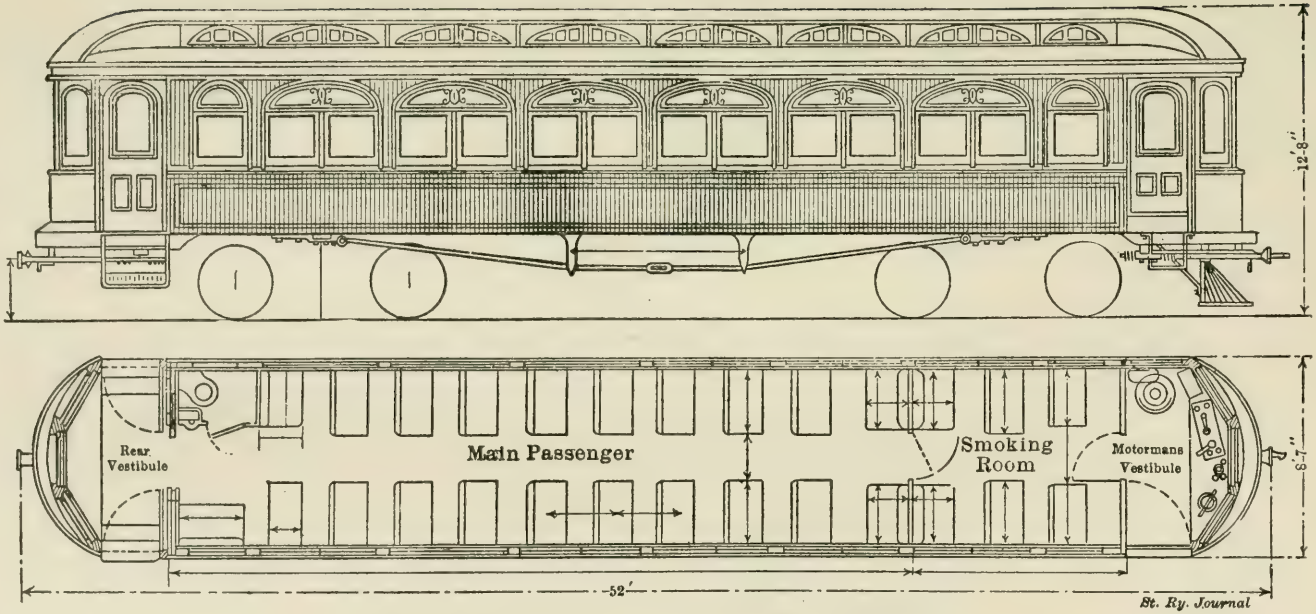
Length over all	50 ft., 4½ in.	Weight equipped	31,350 lbs.
Length over platforms	4 ft., 8⅛ in.	Capacity seating	54
Width over all	8 ft., 8 in.	Capacity standing	57
Weight of car complete	62,800 lbs.		

TRUCKS.

Weight	8,540 lbs.
Speed Rating	54 mi. per hr.
Wheel Base	6 ft., 2½ in.
Diam. Wheels	34 in.
Weight Wheels	645 lbs.
Diam. Axles	5¼ in.
*Weight Axles	540 lbs.

MOTORS.

Number per car	4
Voltage	550 volts
Capacity each	70 horse power
Gear Ratio	2.395
*Weight of Armature	1,000 lbs.
Diam. of Armature	16 in.
*Weight of Gear	287 lbs.



LIMITED CAR FOR LAKE SHORE ELECTRIC

Figure 11. Typical Diagram of Car for Moderately Heavy Interurban Service.—Car No. VI.

TABLE VIII.

Dimensions Typical Electric Cars.—Car No. VII.

50 TON HIGH SPEED INTERURBAN CAR.

Limited Car "Kenilworth," Fort Wayne & Wabash Valley Traction Co.

CAR BODY.

Length over all	61 ft., 6 in.	Weight equipped	56,400 lbs.
Length over platforms	6 ft., 7½ in.	Capacity seating	55
Width over all	8 ft., 7¼ in.	Capacity standing	75

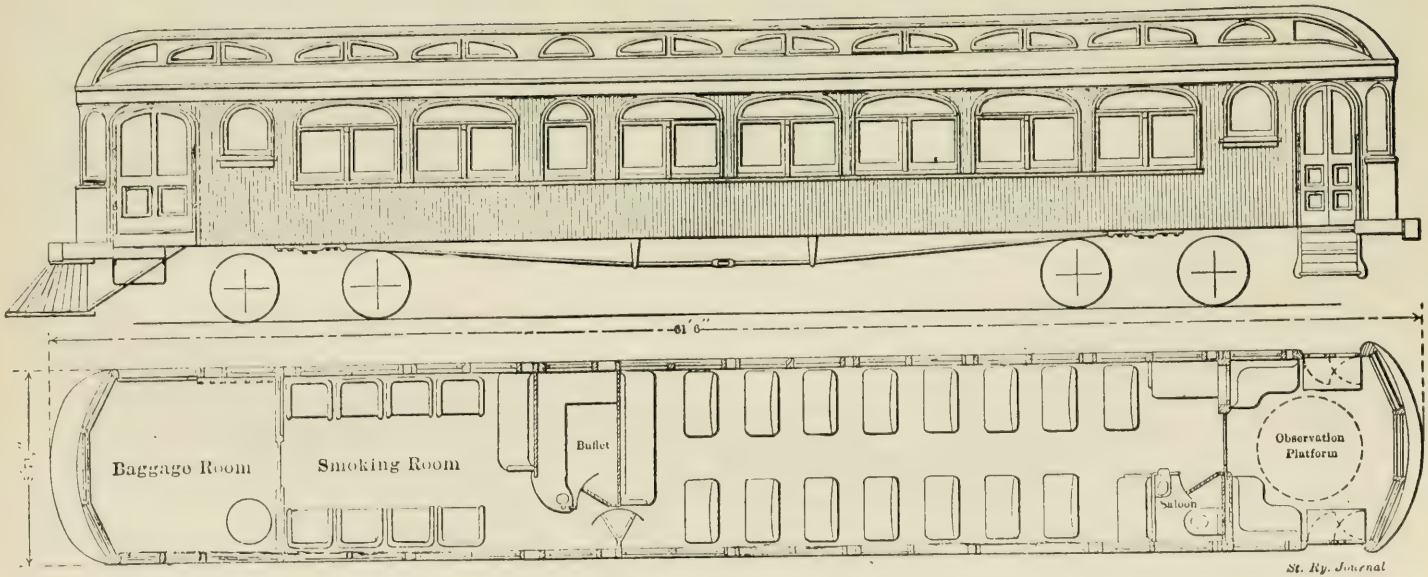
Weight of car complete ..... 100,000 lbs.

TRUCKS.

Weight	12,700 lbs.
Speed Rating	30 mi. per hr.
Wheel Base	6 ft., 5 in.
Diam. Wheels	37¼ in.
*Weight Wheels	1,000 lbs.
Diam. Axles	6 in.
*Weight Axles	650 lbs.

MOTORS.

Number per car	4
Voltage	500-600 volts
Capacity each	90 horse power
Gear Ratio	2.125
Weight of Armature	1,220 lbs.
Diam. of Armature	17 in.
*Weight of Gear	280 lbs.



COMBINATION CAR, FORT WAYNE & WABASH VALLEY

Figure 12. Diagram of Combination Limited Car used by Fort Wayne & Wabash Valley Traction Co. for heavy high speed service.—Car No. VII.

DERIVATION OF EXPRESSIONS FOR ACCELERATION RESISTANCE AND KINETIC ENERGY.

Acceleration Resistance; Motion of Translation.

The general expression for the acceleration resistance of a given car,

$$R = K_1 A + K_2 A$$

is made up of two factors, as has been shown before. They are

$K_1 = K_1 A$ = Acceleration resistance due to translation of car.

$K_2 = K_2 A$ = Acceleration resistance due to rotation of revolving parts.

The former is deduced from the fundamental principle for motion of translation,

$$\text{Force} = \text{Mass} \times \text{Acceleration.}$$

If the force (R) is expressed in pounds, the mass (M) in gee-pounds and the acceleration in feet per second per second, we have,

$$R = M A. \qquad (3)$$

Applying this to the acceleration of an electric car, we have given the weight (W) in tons, and the acceleration (A) in miles per hour per second. Expressing (m) in terms of (W), and (a) in terms of A, we obtain

$$m = \frac{2000\ W}{32.2} = 62.2\ W.$$

$$a = \frac{5280\ A}{3600} = 1.466\ A.$$

Substituting in (3), we have

$$R_1 = m\ a = 62.2\ W \cdot 1.466\ A = 91.1\ A\ W.$$

Knowing the total weight (W) of a given car, we have

$$R_1 = 91.1\ W \cdot A = K_1 A$$

which are the formulas used in determining the values presented in Table I.

Acceleration Resistance; Motion of Rotation.

From the laws of mechanics, we know that the force (F) required to accelerate a rotating body, is the product of the linear acceleration (a_c) of the mass center, and the mass (m). Placing this in the form of an equation, we have

$$F = m\ a_c. \qquad (4)$$

Also we know that the linear acceleration of any point on a rotating mass, is directly proportional to its distance from the axis of rotation. Thus if (a_1) is the linear acceleration of a point on the rim

of a rotating cylindrical body, the acceleration (a_k) of the mass center, will be

$$a_k = \frac{r_k}{r} \cdot a.$$

where (r_k) is the radius of gyration of the body. In the case of the operation of an electric car, we have one rotating element made up of a pair of wheels and the attached axle, revolving at a linear velocity of (A) miles per hour. Applying the laws brought out above, the acceleration of the mass center would be

$$a_k = \frac{r_k}{r} a = 1.466 \frac{r_k}{r} \times A$$

where r_k = radius of gyration of a pair of wheels and axle
r = radius of wheel.

Substituting this value of a_k in equation (4), we have for the force due to the rotation of a pair of wheels and axle,

$$F = 1.466 \frac{r_k}{r} A \cdot m.$$

This expression gives us the force or resistance, effective at the mass center of the wheels and axle. All our considerations in this discussion are based on force or resistance effective at the rim of car wheel; hence we must reduce the resistance (F) to its equivalent value, acting at the rail. This gives us,

$$Rw = \frac{r_k}{r} F = 1.466 \left(\frac{r_k}{r}\right)^2 A\ m. \qquad (5)$$

where (Rw) is the equivalent resistance acting at rim of wheel. But from mechanics, we have the relation

$$r_k = \sqrt{\frac{Iw}{m}}$$

or

$$r_k^2 = \frac{Iw}{m}.$$

in which
Iw = moment of inertia of a pair of wheels and axle.
m = mass of wheels and axle.

Making the substitution in equation (5), we have

$$Rw = 1.466\ A\ m \frac{\frac{Iw}{m}}{r_2} \qquad (6)$$

$$= \frac{1.466\ A\ Iw}{r_k}$$

Hence Rw is the resistance acting along rail, due to the rotation of a pair of wheels and axle.

Where the wheels and axle are on the driving truck, the driving gear is fixed to the axle and revolves with it. So, for the revolving wheel element in a driving truck, we have,

$$Rw = 1.466 \frac{A\ I_g}{r^2}$$

in which

I_g = Moment of inertia of a pair of wheels and attached axle and gear.

In addition to the rotation of wheels and axles, we must consider the rotation of the armature. This revolving element is subject to greater angular acceleration than the wheels, owing to the gear ratio. The resistance due to the rotation of the armature can be expressed by equation (6) if we make the necessary correction for change in acceleration and moment of inertia. The angular velocity of the armature will be the product of the angular velocity of the wheel and the gear ratio; hence we have

$$Ra = 1.466 \frac{A\ Ia\ G}{r^2}$$

in which

Ra = Resistance in pounds at rim of wheel due to rotation of armature.

Ia = Moment of inertia of armature.

G = Gear ratio.

For a car having N pairs of trailing wheels, N^1 pairs of driving wheels and N^1 motors, we have for the total resistance (R_2) at rail, due to rotation of revolving parts,

$$R_2 = N\ Rw + N^1\ R_g + N^1\ Ra.$$

$$= \frac{1.466}{r^2} (N\ Iw + N^1\ I_g + N^1\ G\ Ia)\ A. \qquad (7)$$

For a car having N^1 pairs of wheels and N^1 motors, we have

$$R_2 = N^1\ R_g + N^1\ Ra.$$

$$= \frac{1.466}{r^2} A\ (N^1\ I_g + N^1\ G\ Ia.) \qquad (8)$$

In both of the above equations all the terms become constants for a given car, except the acceleration (A) and they reduce to the form

$$R_2 = K_2\ A.$$

in which K_2 is a constant.

Equations (7) and (8) were used for the determination of the values of K_2 in column A of Table I. All the values of the constants in equations (7) and (8) can be obtained from the dimensions of the particular car in question, except the moments of inertia.

Iw, I_g, Ia. The method determining these three quantities is outlined in a subsequent paragraph of this article.

The equivalent weight corresponding to the inertia effect of the rotating parts, is

$$We = \frac{K_2}{91.1}$$

The values of (We), for the different cars considered in this article are given in column "B," Table III, page 15.

Kinetic Energy; Motion of Translation.

The kinetic energy of a mass (m) moving at a velocity (v), is

$$E = \tfrac{1}{2}\, m\, v^2$$

In a preceding paragraph, we found that

$$m = 62.2\ W$$
$$v = 1.466\ V$$

where W = weight of body in tons
V = Velocity or speed in miles per hour.

Substituting in first equation, we have

$$E_1 = \tfrac{1}{2} \times 62.2 \times W \times (1.466\ V)^2$$
$$E_1 = 66.76\ W\ V^2$$

Knowing the weight (W) of a given car, we have

$$E_1 = K_1{}^1\ V^2$$

which is the equation used in calculating the values given in Table II.

Kinetic Energy; Motion of Rotation.

From mechanics, we know that the energy of rotation (E_2) is

$$E_2 = \tfrac{1}{2}\ I\ w^2$$

where (I) is the moment of inertia of the revolving body and (w) is its angular acceleration. Expressing (w) in terms of V, we have

$$w = \frac{v}{r} = 1.466\ \frac{V}{r}$$

where r is radius of car wheel.

This gives us for (E_2)

$$E_2 = \tfrac{1}{2}\ I \cdot (1.466\ \frac{V}{r})^2$$

$$= 1.074\ I \frac{V^2}{r^2}$$

In the case of a revolving system made up of a pair of wheels and connecting axle, we have

$$Ew = 1.074\ I_s \frac{V^2}{r^2}$$

where r = radius of wheel,

I_s = Moment of inertia of a pair of wheels and axle.

Considering the case of the armature system, we have for the angular velocity (Wa) of the armature system,

$$Wa = Gw = 1.466 \frac{G\ V}{r}.$$

Letting Ia represent the moment of inertia of the armature system, we have

$$Ea = 1.074\ Ia \frac{G^2\ V^2}{r^2}$$

For an electric car, with (N^1) pairs of wheels and (N^1) motors, the total kinetic energy due to rotation, is

$$E_2 = N^1\ E_s + N^1\ Ea$$

$$= N^2\ (1.074\ I_s \frac{V^2}{r^2}) + N^1\ (1.074\ Ia \frac{G^2\ V^2}{r^2})$$

$$= (1.074 \frac{N^1\ I_s}{r^2} + N^1\ Ia \frac{G^2}{r^2})\ V^2$$

All of the above terms are constant for a given car, excepting the speed V, and hence we express E_2,

$$E_2 = K_2\ V^2$$

This equation is the one used in computing the values given in Table II.

Moment of Inertia.

In both the determination of acceleration resistance and kinetic energy, the moment of inertia of the revolving system is an important factor. The moment of inertia of each system, is the sum of the movements of inertia of its respective parts. Thus for the wheel system of a trailing truck the moment of inertia of the system—a pair of wheels and attached axle—is,

$$I_{system} = 2\ I_{wheel} + I_{axle}$$

For a pair of wheels and axle (on a driving truck) we must take into account the gear on the axle and we have

$$I_{system} = 2\ I_{wheel} + I_{axle} + I_{gear}$$

For an armature revolving system, we have,

$$I_{system} = I_{core} + I_{spider} + I_{windings} + I_{shaft} + I_{commutator} + I_{pinion}$$

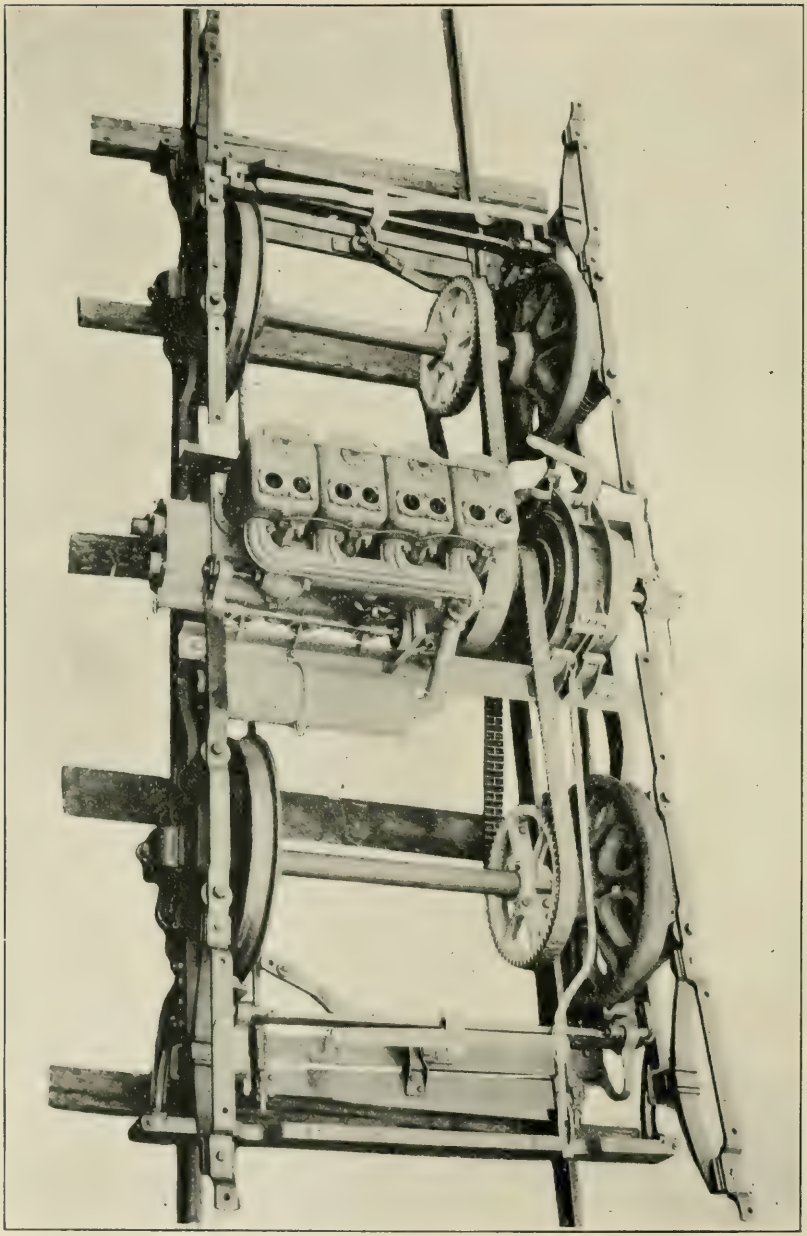
METHOD OF CALCULATING RESULTS.

The method of calculating the results, given in Tables I and II, is as follows: the acceleration resistance and kinetic energy

due to translation, were computed for each car and each condition of loading, directly from the equations

$$K_1 = 91.1\ W$$
$$K_1^1 = 66.76\ W.$$

The acceleration resistance and kinetic energy due to rotation, were determined with unusual pains for one particular car, and then calculated for the other cars, by comparison. The car for which these calculations were made in great detail, is one of the type represented by car No. V, designed for light interurban service. The various parts, composing the revolving system, were measured and weighed. From these data, the moment of inertia of the wheels, armature parts and gear, were calculated. The computations were checked and rechecked, to insure certainty. The moment of inertia of these three parts, for the other cars, were determined by direct proportion. It was assumed that the distribution of metal in the wheel, armature parts, and the gear, was sufficiently similar for the different sizes, to permit making such an assumption safely.



GASOLENE TRACTION ON RAILWAYS.

W. B. Greene, M. E., '08.

The present development of the independently operated motor-car is filling a long felt want. The high cost of the installation of electric equipment on interurban roads often prevents its use where the traffic is comparatively light, whereas an independently operated car can be run at a profit. The small capital investment of the latter enables it to carry its own interest very easily without the necessity of doing a certain amount of business in order to make a profit. The independently operated car is also needed in other fields besides that of the small road. Electric lines can make a considerable saving by using the independent car for owl service and shutting down the generators for half the night. Branch line feeders of steam roads can give better service by operating independent cars more frequently, instead of running one or two trains daily. It is almost a necessity for use as a wrecking car and work car on electric roads.

To fulfill this demand some few firms are making cars which are proving satisfactory, although the industry is still in its infancy. The Union Pacific claims its large interurban type gasolene cars to be operating very successfully. Other independent firms are at present manufacturing cars some of which are proving their economy. This is such a new field, however, that all difficulties could not be overcome by the designers, although the present use is showing that the problem is being solved very practically. Different designers are looking at the problem in different lights, some using a very heavy car and others going to the other extreme. On account of the class of service which is required of this car it is probable that the car to succeed will be a happy medium, more on the order of a large street car than a double truck interurban or a very light car. The public will have to be treated as well as with the other kinds of service and at the same time operating expenses cannot be materially increased.

The principal obstacle to be overcome is vibration. In order to compete with the electric car the gasolene motor must be suspended so that it is as little affected by the vibration of the rails as is the electric motor. If mounted directly upon the trucks the direct vibration from the rails is very hard upon the motor and it would be almost impossible to run a distance of twenty-five miles without jarring all the nuts off the connecting rod bolts.

Probably the car nearest the solution of the difficulty is one in operation on the Aurora-DeKalb Line which, although possessing several faults, has demonstrated its practicability. These cars

go to neither extreme in weight. They are single truck, semi-convertible cars divided into passenger and smoking compartments; the smoking compartment being used also for baggage. The length is thirty-six feet over all and the seating capacity is thirty-two passengers. The cars are vestibuled and arranged for double end operation. Brill 21E trucks are used with 33" cast iron wheels.

The motor used is a vertical, four cylinder, four cycle, 7" x 7" engine and was designed especially for street car service. It is extremely simple and very substantial, all parts being very heavy. The crank shaft and connecting rods are particularly heavy and well proportioned, as these are the weak spots in such an engine. The crank case is cast in one piece with hand holes at the sides so that all parts are accessible for inspection and repairs. Lubrication, which has to be especially good in order to compete with the electric motor, is very well taken care of by a sixteen feed mechanical pump and the splash system. The bearings are of phosphor bronze with babbit inserts. The inlet and exhaust valves are situated side by side in one chamber and operated mechanically from one cam shaft. The carburetor is attached to the cylinders by an equalized manifold and is of the float feed type. Exhaust passes down to the muffler through a ribbed manifold.

The cylinders are water jacketed and the water used for heating the car. The natural circulation is sufficient for the water to be forced through the two radiators at the ends of the car and up to the storage tank on top. The gasolene tank is situated under a seat in the smoking compartment and is connected to the carburetor by a flexible copper tube.

The engine is mounted by the three point system of suspension so that no bending strains are imparted to the engine. As is shown in the figure it is situated at the center of the truck parallel to the car axles, thus getting the benefit of the coil springs on the truck. In the later design a heavy bed plate has substituted for the angle iron shown as supporting the engine. This is for the purpose of absorbing vibration which has caused considerable trouble on these cars. Another change on account of the vibration is in the connecting rod bolts. Heretofore they have shown a tendency to crystalize and break, so that now vanadium chrome steel will be substituted for the carbon steel previously used.

Transmission is through Morse Silent Chains direct to the car axles. In order to provide for the slack in the chains the journals are cast with a thick lip on one side, which with a wedge allows for $\frac{3}{4}$" slack; when this point is reached a link may be removed and the original adjustment repeated. A system of planetary gears on the engine shaft is used for low speed. For high speed a multiple disc clutch locks the whole and the mechanism acts as a flywheel.

The control of the engine is from either end of the car, there being three detachable controlling handles. Three points are on the controller, slow, neutral and high speeds; the handle being similar to that of a hand brake. It is so arranged that high and low speed can not be in at the same time. The throttle and spark levers are similar to air brakes handles. No reversing mechanism is employed on account of the added weight and machinery; to start the engine in either direction it is cranked from the two sides and kept running till the end of the trip, when the engine is reversed and cranked in the opposite direction. The engine is kept in motion during the short stops.

The average running speed is 25 miles per hour, though 30 or 35 can easily be reached. The weight of the engine and trasmission is about 5,000 pounds and that of the car complete ten or twelve tons. As the cars are run on this line with frequent stops the fuel consumption is about six miles on a gallon of ordinary stove gasolene or 120 miles per day on 20 gallons.

POWER PLANT COSTS.

G. E. Phisterer, M. E., '08.

It is indeed noteworthy to see the great advance made in all engineering lines in the last decade, with the result that modern engineering practice has become a model of economy. Also is it true that the modern engineer must devise ways and means to attain the greatest practicable economy in any line he undertakes, no matter whether it be the design of a great power plant or a small simple engine or machine; the same end must be accomplished—economy. Economy of operation is the keynote of good design and without it the plant or the machine may become useless, and be thrown upon the great scrap-heap of failure.

To all consumers and generators of steam the hope for a continuance of dividend paying power lies in the possibilities of decreased cost of production. Many things enter into the cost of production, which can probably be reduced and which consequently will reduce the cost of power. However, the exact determination of the cost of operating any given power plant is nearly impossible, presenting as it does, problems that do not admit of mathematical computation. Further, no one plant can be picked out to represent some certain class, owing to the particular features connected with each individual plant, and the conditions characteristic of but one plant alone. Again, the data on the subject of power plant costs is difficult to procure, partly because some plants have no systematic method of keeping it, and partly, on account of the reluctance of station managements to publish records of performance and cost records. However from an analysis of these costs the following heads or divisions present themselves:

First, First cost.
Second, Fixed charges.
Third, Salaries of officials and wages.
Fourth, Fuel cost, and
Fifth, Miscellaneous expenses.

Under the head of "First Cost" much could be said with regard to power plant costs. Of course the size of plant, the location, and the nature of the output will generally determine this point. In most cases the power plant will include the boiler equipment, the generating plant or prime movers, condensers and auxiliaries, the coal handling machinery, and probably other features depending on the kind or the nature of the output. All of this equipment may be in one building or may be in a set of buildings, all of which have a direct bearing on the power plant first cost. From late statistics the floor space occupied by steam turbine generating units, which may be taken roughly as $\frac{1}{4}$ of the horizontal Corliss

and ⅓ of the vertical, is from ⅕ sq. ft. in the smaller sizes to 1-20 sq. ft. per generator H. P. in the larger sizes. Where real estate values are high, the engineer must make his selection to secure economy and keep down the first cost at the same time.

Every power plant must necessarily experience a deterioration in some of its parts. If it does not all break down at once, one part will give trouble at one time and another part at another time. The machine, in time wears out and must be replaced; the land which the plant occupies may increase or decrease in value, and the prevailing price of stocks may be high at one time and possibly low at another. The bonds will bear interest and the interest must be paid; the taxes will come and the insurance, also, must not be overlooked. These, then, are some total fixed charges on capital cost, which must also enter into the fixed charges. Summing up the fixed charges, we have:

(a) Bond interest, Taxes and Insurance.
(b) Sinking fund, including depreciation and maintenance.
(c) Total fixed charges on capital cost.

After the power plant is erected and ready for operating the question arises, "who will run it to give the maximum economy?" Some plants are run by incompetent men who cannot get the most out of them. It is no easy matter to select an engineer to operate a power station, and in some cases money is lost in operation through the inability of the engineer operating the plant. Not only in the executive positions but in general, with all labor connected with the plant, from the fireman in the boiler room to the chief engineer himself, choice of selection must be considered. It is very plain that high-priced low economy men must be removed in order to get the maximum efficiency of the plant. Boiler room labor is probably the greatest item in the ordinary steam plant, and this varies from 3% to 8% of the total costs. Oftentimes, on account of variation of equipment, character and load, the labor charge on plants of similar design and capacity varies as much as 50%.

The important point of fuel needs careful consideration in any power plant, since it is by far the greatest of the total operating expenses. Whether it be alcohol, peat, wood, oil, or coal, a saving of 1% in the fuel bill is no small item in a large station. Naturally, the fuel used will be, in most cases, that which is most convenient to get and that which costs the least.

Many times the coal analysis is disregarded and the engineer burns coal, because it is cheap. A deeper investigation than mere price, should be made, for in some cases it has been found that the consumer burns twice or three times as much of this "half stone" at $1.00 a ton, whereas if he bought a better grade at $1.50 per ton, he would save money in the end. Too often the price is an indication of the fuel burned. Any competent engineer will con-

sider, besides price, quality or heating value, and the use to which it must be put. Cases have arisen where coal at $.90 a ton was cheaper to burn than coal at $1.30 a ton with nearly twice the heating value. Social conditions must always be taken into account and a careful study made before the fuel is finally selected. Coal is conceded to be the most common fuel and forms the basis of estimates of fuel charges.

In a 2,000 K. W. steam electric station in Illinois, the total cost of operation per K. W. hour during the year 1905 was .443c, not including fixed charges which would add approximately .06c, making a total of .503 cents. The price of coal in this case was $.75 per short ton, delivered at the station, a price very much below the average for steam electric plants in that state, where the average of 300 plants is about $1.35 per short ton. The fuel cost per K. W. hour was .219 cents, 43% of the total cost, or 49% of the cost per K. W. hour, not including fixed charges. This represents very good economy for a station of this size and the values given may be taken for estimates on most modern and approved practice. The fuel charge in any given case may be estimated by a comparison of coal values per short ton.

In the above enumerated costs, there is more of a definiteness than that which characterizes the determination of the miscellaneous supplies. It is exceedingly difficult to derive any very definite conclusions in this regard, since so many indefinite things enter into the consideration, such as type of machinery, local cost of materials, freight rates, and the personal equation of operators using oil and waste. Under this head, the following items are usually included:—oil, waste, repairs and other miscellaneous supplies. Unfortunately, records of supply charges are greatly at variance, and from data collected by the writer it is seen that these costs bear little or no relation to the size or output of the plant, but are more or less dependant on the labor. For example, in one plant in Illinois of 2,000 H. P. the miscellaneous expenses were $582.00; in a plant of 4,800 H. P. they were $22,140; another plant of 5,300 H. P. the miscellaneous expenses were $903.78. Then another plant, a turbine plant of 10,500 H. P. has costs amounting to onlly $2,705.75. In some plants one item is high, while another is very low. In steam turbine plants these costs are probably lower than in reciprocating plants, for the cost of lubrication is much lower. In the 2,000 K. W. steam electric station using coal for fuel, mentioned above, the oil and supplies charge was 2½% of the total expenses, the latter item including maintenance, but none of the other fixed charges, viz., interest, depreciation, taxes and insurace.

The up to date power plant will consist of good equipment and buildings, designed for economy. Operating expenses will be reduced as much as possible and the cost of power minimized. An-

alysis of the total power costs of modern steam plants of 5,000 to 10,000 K. W. capacity show that the capital costs, including interest and depreciation, amount to about 50% of the total. For such high grade stations, with thoroughly modern equipment, we should expect an investment cost of from $150.00 per K. W., in the smaller down to $100.00 per K. W. in the larger sizes. In a very few large stations the investment cost has been less than $100.00 per K. W. Compactness saves money in regard to floor area and buildings. The right kind of fuel must be considered and used; and the operating engineer must always be on the watch to gain efficiency and reduce the cost of power, and consequently the power plant costs.

THE PROBLEM OF THE SMALL GAS PRODUCER.

R. E. Robinson, M. E., '08.

The steady improvement in producer-gas power-plant design, as regards initial cost and reliability of operation especially, is bringing this type of installation deservedly more and more into favor. With increased confidence comes application to more diverse classes of work, which naturally introduces new problems of design. An interesting phase of the subject, and one of considerable importance, is seen in small plants of less than 100 to 150 H. P. At present the suction type of producer is used exclusively in these plants, making it necessary to use anthracite coal, coke, or charcoal as fuel, since no suction-producers as now put on the market have demonstrated their ability to run on bituminous coal or other tarry fuels; and in spite of the favorable showing of the suction-producer operating on anthracite as compared with the best steam plants of like capacity, the constant upward tendency of prices makes the utilization of low-grade fuels a most attractive field for investigation.

The difficulty in the way of this project lies in the tarry distillates from bituminous coal. This tar, volatilized in the producer, condenses in the pipes and valves unless it is removed from the gas or "cracked" into compounds that remain gaseous at ordinary temperatures. Several European manufacturers, and at least three in America, build producers that are commercially successful in sizes above 200 H. P., but all of these may be put into one of two classes which are well represented by two American installations, and all are open to the same objection in the smaller sizes. The Taylor pressure producer, put on the market by R. D. Wood & Co., of Philadelphia, eliminates the tarry vapors by means of a scrubber and tar-extractor, and it is a 250 H. P. Taylor apparatus with which the United States Geological Survey Fuel-Testing Plant at St. Louis secured such remarkable results in 1904-'06. The Loomis-Pettibone, which, as well as the above-mentioned producer, has been too often discussed in recent technical publications to require detailed description here, is a down-draft apparatus in which the tar is fixed as a permanent gas and sooty impurities are burned to CO by passing the products of distillation though a thick incandescent fuel-bed. Both of these installations are commercially successful in large sizes, their manufacturers guaranteeing a fuel-economy of something like 1.25 lbs of medium bituminous coal per H. P. hr., and claiming as low as 1 lb. per H. P. hr. at the generator-terminals as a fair average performance.

In sizes below 250 H. P., however, the scrubbers and tar-separator of the former, the complicated gas-generator of the latter,

and the large gas-holders required by each, so increase the initial cost as to offset by the higher fixed charges the saving due to the use of cheap fuel, as will be seen on inspection of the accompanying table.

Type.	Size H. P.	Total H. P. Hrs. Per Year.	Initial Cost	Fixed Charges Per Year.	Operating Expenses Per Year.	Cost of Power C. Per H. P. Hr.
Loomis-Pettibone	5500	30,061,120	$385,000	$50,640	$60,995	0.376
Loomis-Pettibone	2000	9,857,440	127,500	19,965	22,984	0.523
Loomis-Pettibone	500	1,531,430	35,000	5,483	6,290	0.97
Loomis-Pettibone	250	472,020	23,200	3,574	2,727	1.27
Otto, Suction.....	110	330,000	5,200	1,035	1,353	0.72
Otto, Suction.....	60	180,000	3,050	699	908	0.88
Steam	1000	3,000,000	85,000	9,000	11,031	0.668
Hydro-Electric ...	1000	3,000,000	105,000	10,550	4,300	0.498

NOTE.—The figures for gas plants are adapted from data given by Mr. R. H. Fernald in a paper presented before the Western Society of Engineers, on "The Present Status of the Producer-Gas Power-Plant in the United States." The suction-producers, also, have no electrical apparatus in connection, and consequently should have their operating-cost increased by about .1c per H. P. hr. to cover the expense of electrical transformation.

From this table it appears that a 500 H. P. pressure is very near the margin of economical operation, while the 250 H. P. unit is beyond it as compared with a suction-producer of only half the capacity, operating on anthracite coal. This difference in favor of the suction-plant is being steadily cut down, but not in the most desirable way, by the growing scarcity of anthracite coal—ground is rather being lost by the suction-producer than gained by the other types. The needs of the small power-consumer near a manufacturing center are of course best taken care of by large central stations which either generate and distribute electrical power as do the Fisk Street Station of the Commonwealth Electric Co. and the Niagara hydro-electric plants, or distribute gas for power purposes as is a not uncommon practice in continental Europe and England, where large by-product gas-plants of the Mond type are in operation, recovering the various by-products and delivering gas at a considerable distance. In the case of isolated plants, however, where excessive transmission-losses make these arrangements impracticable, there is

a large and by no means decreasing field for economical plants of small capacity. It is evident then that, even aside from its probable value as applied to large plants, any successful investigation of a small gas-producer will be well worth while.

As to the general direction of such investigation, it would seem to be naturally fixed by the fact that the present unsatisfactory conditions occur in the producer and cannot be materially affected by the behavior of any engine or engines operating on the gas. The relation here is closely analagous to that of the steam boiler and engine; the operation of the producer will depend not on the characteristics of the engine, but rather on the conditions which may almost be called inherent in itself, as for example fuel-bed temperatures, intensity of draft, etc. In steam practice boiler and engine are never tested as a single unit when it is desired to locate and remedy some trouble known to exist in the boiler-equipment, and by a similar course of reasoning one reaches the conclusion that it is a needless complication, in the early stages of the work at least, to combine a study of a gas-generator with tests of a gas-consumer. It is quite true that the mechanical efficiency of the gas-engine is low, leaving room for great improvement at that point, but the main idea of the present consideration is to arrive at some method of making a clean, combustible gas, free from constituents detrimental to valves and fittings, from inferior fuels without the use of expensive or complicated apparatus; and it is unlikely that gas-engine tests run in connection with the producer, diverting the attention from the main object of the work as they must, will give data of a value commensurate to the added difficulty and expense.

Of at least equal importance with aiming the investigation in the right direction is carrying it out in the right way. It is necessary to proportion the scope of the investigation to the facilities available, not attempting either to cover too much ground experimenally or to generalize conclusions from insufficient data. The first thing to look out for, however, is the tendency of the so-called "practical experimenter" to dispense with theoretical analysis altogether, to put in a pressure-gage here, and a thermometer-cup there, analize a few samples of coal and gas, throw the data together and call it a test, never stopping to think that by this very haste to "get results" he is defeating his own ends. The preparation for any experimental work should be a most thorough study of all the information at hand on the given subject and a close analytical consideration of the problem. Too many investigators attempt to carry on advanced research and expect to draw correct conclusions without sufficient knowledge of the principles underlying their work. If progress in this line is to be made by scientific study rather than rule-of-thumb methods, the first step after the theoretical analysis, and hardly separable from it, is a series of tests to obtain accurate,

reliable data giving definite knowledge of the chemical reactions going on in the fuel-bed, their causes, and the temperatures at which they take place under present normal operating conditions, and giving means of learning the physical and chemical laws governing these reactions. This being done, experiments should be carried on to determine the effect of changing, one at a time, the various items such as initial temperature of the blast, percent of moisture supplied, intensity of draft, rate of combustion, depth of fuel bed, etc., keeping always in mind the idea of studying the data with a view to learning the natural laws which govern every stage of the process and by virtue of which the changes in conditions produce the results secured. An experimenter working on some such scheme as the foregoing, and at the same time recognizing the value of an occasional lucky guess, is the one who is going to find out just what can and what can not be done with a small gas-producer.

THE HEATING OF FEED WATER FOR BOILER PURPOSES.

THEODORE WEINSHANK, M. E., '96.

In preparation of this paper I take for granted that at least a few chemists will read it and I have, therefore, endeavored to present the subject as simply as possible so far as pertains to the engineering feature. It is not the intention to show the advisability and necessity of the heating of feed water for boiler purposes, as that is a mere matter of heat units, but rather the purification of water for boiler uses. The purification of water for boiler purposes is so simple that a deep knowledge of chemistry is not necessary in order to understand the principles involved.

WATER IN GENERAL: Water is a combination of two elements, hydrogen and oxygen, in the proportion of two parts hydrogen to one part oxygen. If a mixture of the two elements are brought together in the proper proportions, and a flame applied, they will unite and form water.

99% of the water on earth is in the oceans. From the oceans the water evaporates and rises and is carried away. When the clouds that carry this vapor come into contact with cool currents of the air, the moisture of vapor condenses, and rain or snow is formed. When the rain or snow strikes the earth, a portion of it runs away on the surface and forms small rivulets, and these streams in turn form rivers and lakes, and these in turn, empty into the ocean.

A portion of the water which flows on the earth is absorbed by the soil and after passing through the strata of the earth, appears in the form of springs, or, beneath the surface, is reached by means of wells.

The water used for boiler purposes, if used before it has passed through the earth, (or, in other words, if rain water could be obtainable for boiler purposes), would be considered as the best feed water, because it contains only those impurities which the drops have absorbed from the air, and a small portion of carbonic acid gas. It is well known that rain water is a great solvent and under ordinary atmospheric pressure, would dissolve its own carbonic acid gas. But when rain water passes through the soil and through various rock, it comes in contact with mineral salts which will dissolve. The water dissolves them and carries them along in solution. If rain water flows in a region where the rock is granite or slate or some other insoluble substance, it does not dissolve much of it, but, if it passes through a region where the predominating rock is lime, sand, or a strata that contains compounds of lime and

magnesia, then the rain water dissolves these and causes the water to be what is known as hard.

Decaying vegetation also gives up to the water flowing over it a number of acid combinations and certain organic impurities which have a serious effect on the nature of the water when considered for boiler feed purposes.

From the above you will note that water for boiler purposes may be influenced by the following:

First, by the kind of rock, or local conditions of vegetation.

Second, by the depth to which it penetrates.

Third, by the time it remains in the earth.

The ideal water for boiler purposes is one that does not deposit scale, does not corrode and does not cause the boilers to foam. Unfortunately such water does not exist in nature.

I mentioned the term hard water; and the cause of this being the amount of lime and magnesia held in solution by the water. In order to make it more explicit I will endeavor to subdivide the hardness of the water into two kinds—the temporary hardness and the permanent hardness.

Temporary Hardness: Temporary hardness is due to carbonate of lime and carbonate of magnesia held in solution by carbonic acid gas. The latter has been absorbed as stated above, from the air. By boiling this water we drive off the carbonic acid gas, and it causes a chemical decomposition and forms a deposit of insoluble carbonate of lime or carbonate of magnesia.

Permanent Hardness: Permanent hardness is due to the solution of the sulphates of lime and sulphates of magnesia. These elements remain in solution in the water after it has been boiled, because they do not depend upon the carbonic acid gas to hold them in solution.

From the above you will notice that a large portion of scale formation is due to the presence of four elements; carbonate and sulphate of lime and carbonate and sulphate of magnesia. If we could provide means by which we could get rid of these four elements, we would prevent scale forming in the boilers. The carbonate of lime and magnesia alone do not form a very hard scale, but it is bulky because, when crystalizing, carbonate of lime combines with many times its weight of water.

The white chalky matter that is washed out from the boilers, and which can often be found about a boiler house, is the impure carbonate of lime. If, however, we could provide means by which we could boil the water before it enters the boiler, or, in other words, if we can provide a feed water heater that will bring the water up to boiling point before it is pumped into the boiler, we will provide a means to deposit the carbonate of lime and magnesia in the feed water heater before it is pumped into the boiler. If, however,

an open type of feed water heater is not installed to boiler the entire supply of water, then chemicals can be used, which, when added to cold water, will combine with the carbonic acid gases in it, and thus remove them from the water. Once the carbonic acid gas is removed, the carbonate of lime and magnesia will deposit and form a sediment.

The one chemical most available for this purpose, because of its great abundance and low cost, is the common building lime or the so-called quick lime. It is no more or less than a compound of lime and oxygen. When common lime is mixed with water it forms what is called slack lime. When slack lime is added to water containing carbonate of lime in solution which is held by carbonic acid gas, then this carbonic acid uniting with the slack lime forms carbonate of lime and settles down as a sediment.

From the above it will be seen that there are two ways of removing temporary hardness from the water; either by bringing it to a boiling point, or by applying slack lime, and allowing the carbonate to settle in a tank, or other vessel.

Sulphate of lime is commonly known as plaster paris. Its scale is not thrown out of solution until the water is heated up to about 302 degrees Fahrenheit, which is equivalent to 55 lbs. boiler pressure. Sulphate of lime, after being precipitated in the boiler, unites with such other deposits as are in the boiler and forms a hard cement-like scale. It is a very poor conductor of heat. Being soluble in water, it is free from carbonic acid gas, and cannot be removed by means of slack lime. But it can be removed by means of carbonate of soda, or the so-called soda ash. The action takes place as follows:

When the water, containing sulphate of lime dissolved in it, is mixed with the water solution of carbonate of soda, a chemical action takes place, namely; sulphate of lime plus carbonate of soda react and form carbonate of lime and sulphate of soda. The sulphuric acid which was originally combined with the lime, leaves the lime and combines with the soda, forming sulphate of soda, while the carbonic acid gas which was combined with the soda leaves the soda, and combines with the lime, forming a carbonate of lime. The carbonate of lime settles down as a white sediment, while the sulphate of soda remains in solution. Therefore, to remove the sulphate of lime from the water, before it enters the boiler, it is necessary to add to the water the proper amount of soda ash required to combine with the sulphate of lime, allowing the white sediment to settle down.

Sulphate of Magnesia: Sulphate of magnesia is commonly known as Epsom Salts. Sulphate of magnesia of itself does not form a boiler scale, but when in a boiler with carbonate of lime, unites with the latter and forms a sulphate of lime and hydrate of

magnesia. These two compounds form a very hard stonelike scale. Sulphate of magnesia can be removed from the water before it enters the boiler by caustic soda, or soda ash and slack lime.

From the above, you will note that the scale in boilers is due to the following five causes:

First, deposition of lime and magnesia due to the boiling off of the carbonic acid gases of the water in which they were dissolved.

Second, deposition of sulphate of lime due to high temperature in boiler.

Third, deposition of magnesia compounds due to their decomposition in the water.

Fourth, deposition of sand, clay, and other matter that was suspended in the water.

Fifth, Organic matter.

The first difficulty can be overcome either by boiling the feed water or by means of a settling tank. The second and third can be overcome with caustic soda or soda ash, and the fourth can be overcome with a good filterer.

To overcome the first, a boiler house must be provided with a proper open type feed water heater. It is often the problem with the purchasing agents where they can buy the cheapest feed water heater, disregarding the quality and quantity of water their poor operating engineer must handle. In order to remove all the carbonate of lime and magnesia from the feed water heater, the construction of the heater must be such as to divide the cold water before it comes in contact with the steam into a very fine spray, or small drops, so as to give the steam an opportunity to come in contact with the entire body of water, and thus bring it to a boiling point instantaneously.

The next and most important point is to have, in the heater, volume enough in the steam space so as to give the water and steam low velocities, which would help considerable to heat the water to a high temperature, thus removing all carbonate of magnesia or lime.

To remove the second and third cause of scale formation a provision must be made in the feed water heater by which a sufficient amount of soda ash can be admitted into it before the water is pumped in the boiler. In other words the boiler is not a retort in which to produce chemical reactions. If the water is to be subject to chemical treatment, it must be done outside of the boiler, either through feed water heater or settling tank, or both, as it is the only way by which scale formation can be successfully prevented.

To remove the fourth cause of scale formation, a proper filter, which is an essential part of the design of a good feed water heater, must be provided and properly cared for.

The fifth element only forms scale by decomposition and the

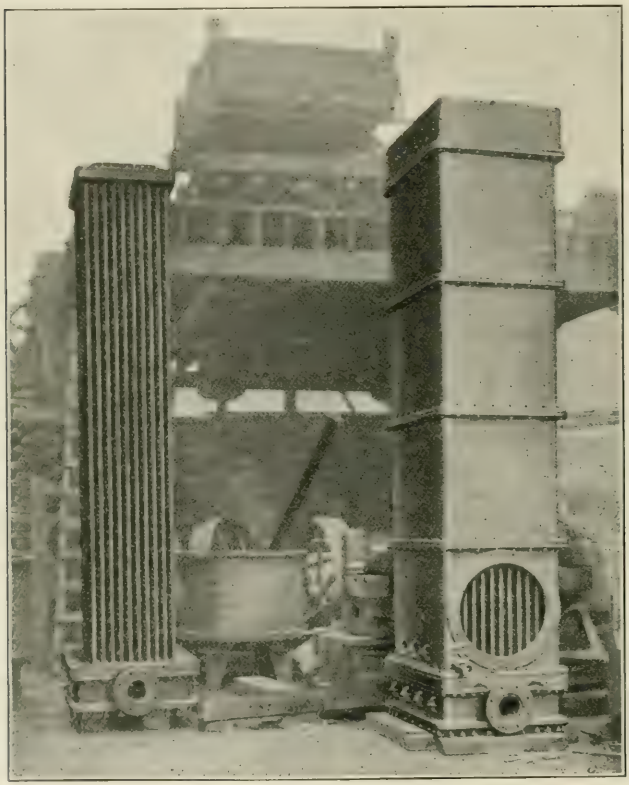
formation of acids which combine with some of the permanent bases. Their effect is usually to produce corrosion, which is overcome by addition of suitable neutralizing agents to take care of the acids.

There are three types of heaters now in use:

THE CLOSED.

THE THOROUGHFARE.

THE INDUCTION.



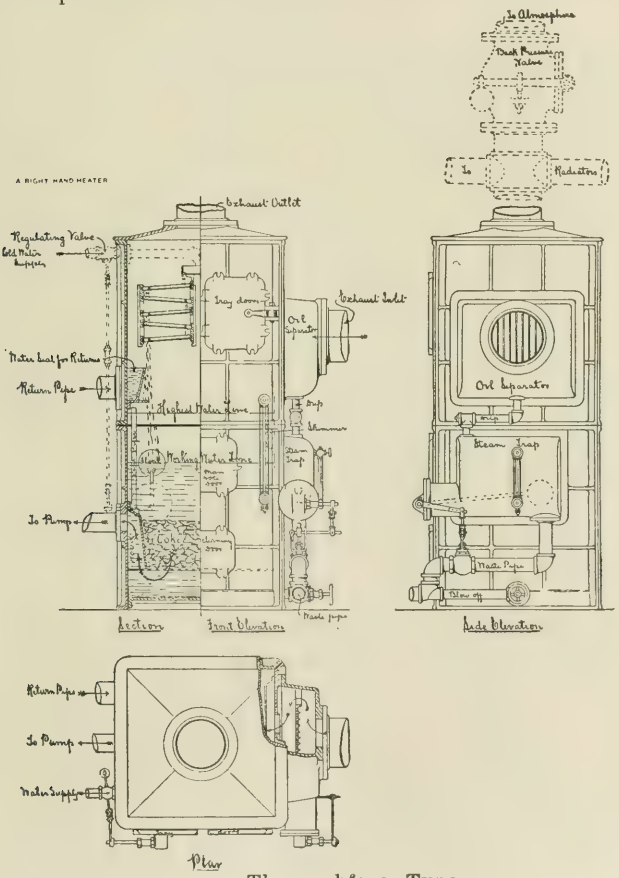
Closed Type.

The operation of the closed type is as follows:

The feed water for the heater is admitted to one of the end chambers, forced by the pump through the first series of brass tubes into the upper chamber, from thence downward through the second series of tubes to the second sediment chamber, and so on until it reaches the fourth and last chamber, from which it travels to the boiler. In other words, the water travels through the tubes up

and down until it passes through the entire system of tubes to the boiler.

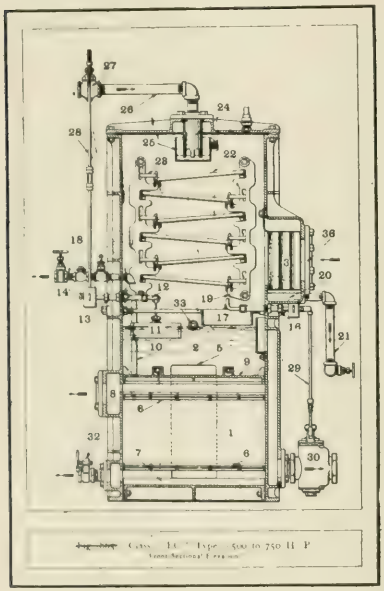
The exhaust steam to the heater is introduced on the outer shell by a flange connection. By an arrangement of baffle plates it circulates freely and evenly amongst the brass tubes, imparting its heat to the feed water inside, and passes out on the other side to the atmosphere.



Thoroughfare Type.

From the above description, it is plainly seen that the pressure in the discharge must be equal to that of the boiler pressure plus any amount required to overcome the friction of the water in the tube to lift the check and other friction losses. The water handled by the pump is cold and whatever impurities there are in the water will be either forced through the brass tubes and into the water

heater, or, if the water becomes hot enough in its travels through the tubes so that it will deposit carbonates of lime and magnesia, it will coat the tubes inside and if the amount of lime is great, it is only a question of time until the tubes will become so coated that they will be absolutely useless. To clean a heater of this type is almost equivalent to rebuilding it. As the breaking of the joints that must be kept up tight under boiler pressure is no small matter and to remove the lime and scale from the interior of a 1½″ or 2″ tube is no easy process, unless special tools, made for this work are obtainable, this type of heater is almost prohibited in the state of Indiana, northern part of Michigan, and northern part of Wisconsin, where there is considerable permanent hard water in use.



1. Filler Chamber.
2. Heating Chamber.
3. Oil Separator.
5. Down-cast.
6. Filter-Screens.
7. Settling-Chamber.
8. Hot Water Outlet.
9. Division Plates.
10. Relief-pipe.
11. Open Sink-Pan. (Water Supply.)
12. Sink-Pan Rod. (Water Supply.)
13. Stuffing Box. (Water Supply.)
14. Counterbalance-Weight. (Water Supply.)
15. Counterbalance-Weight. Overflow.)
16. Stuffing-box. (Overflow.)
17. Open Sink-Pan. (Overflow).
18. Vent and Inlet Air-Valve.
19. Tray-Bra kets.
20. Oil Separator Chamber.
21. Separato Drain.
22. Heating Tray.
23. Tray-Locking Device.
24. Water,Inlet Seal.
25. Wa er-Inlet Trough.
26. Cold Water Supple-Pipe.
27. Cold Water Regulating-Valve.
28. Connecting-Rod. (Water Supply.)
29. Connecting-Rod. (Overflow.)
30. Overflow-Valve.
32. Drain to Waste.
33. Stay-Bolt.
34. Gauge-Glasses.
36. Exhaust Steam Inlet.

27

Induction Type.

The thoroughfare type of heater is one of the open type in which the entire supply of exhaust steam is forced into the heater at an opening left on top of it from which the surplus exhaust may flow to the atmosphere. This arrangement works very satisfactorily under all conditions where the surplus of exhaust steam is being wasted to the atmosphere.

The description of the operation of the Thoroughfare heater is fully described under the next type of Induction Heaters, with the two exceptions, namely, that the entire exhaust is made to pass through the heater and the water is being filtered downward. The operation of this type is satisfactory, as explained above, but when

the surplus exhaust steam is being used for heating purposes, then the steam which passes through the feed water heater is almost at a point of saturation, and at the moment it strikes the cold surface of the steam pipe it deposits this water there, and the heating system must handle too much water without getting any benefit out of it. In addition to this the amount of water that the exhaust will carry away within its folds is nearly equivalent to the amount of exhaust steam condensed to heat the feed water.

The Induction type heater is of the same open type as the Thoroughfare, only it is so constructed that the amount of steam required to heat the feed water is introduced into the heater by the mere fact that cold water coming in contact with steam creates a partial vacuum and thus by differential pressure the requisite amount of steam is drawn into the heater and there condensed, thus accomplishing two fold results, heating the feed water and condensing a certain amount of steam, and saving this condensation.

Boiler Cleaners: The boiler compounds in the market being so numerous that it is impossible to refer to all of them, I will mention only a few of them in a general way. There are some that are entirely mechanical, such as wire plates, brushes; others are supposed to have a chemical action, still others like potatoes, peas, moss, kerosene, etc., are of some little benefit, because they form centers about which lime and magnesia gather, and thus prevent a formation of hard scale.

Some chemicals used, and which are called boiler compounds, are humbugs, and some were found to be more harmful than good to boilers; but nearly all of the boiler compounds, so far as giving fairly good results, contain a certain amount of soda ash, disguised and discolored as a rule in such a manner that it takes a chemical analysis to detect it. Even if the soda ash, if improperly used, will do more harm than good to the boiler. But if any engineer will learn to know the value of his blow-off and remove the so-called sludge, the results will be fairly satisfactory.

Carefully considering all the boiler compounds, and taking into consideration what has been stated above, it will be agreed that there is no necessity of having any scale in the boiler if the water is treated properly before it is pumped into the boiler.

From a financial standpoint, if the owners of manufacturing plants would but realize the loss of fuel due to the scale, the price of coal would be the second consideration. The first consideration would be to keep the flues clean. As an example, will state that from a table prepared by Mr. W. S. Hutton, I find that scale $\frac{1}{8}''$ thick will waste 18% of the fuel; a scale $\frac{1}{4}''$ thick will waste 38% of the fuel and in some part of Indiana where I have found scale to be $\frac{3}{4}''$ thick, the loss of fuel has been as high as 90%. Even taking the cost of fuel to be $1.00 per ton, which is the cheapest in Indiana, the loss due to scale in the boiler is too great to be ignored.

SOME MATTERS OF COST WHICH AFFECT DESIGN, AS ILLUSTRATED IN THE MANUFACTURE OF ELECTRICAL MACHINERY.

E. H. Waldo, M. E.

The statement that Machine Design is getting out the best machine for the least money, is not by any means a scientific definition of the term, but it tells a large part of the story. It is well recognized that the "best" machine is itself always a compromise between conflicting components. To take an illustration from electrical machinery, it is, in general, desirable that a dynamo should be as light as possible, but if we cut down the material too far our machine will overheat. It is desirable that a transformer should have both high insulation and good regulation, but generally the better the one the poorer the other quality, other things being equal. Good design must secure the proper balance of the various elements to get the "best" machine.

But the designer soon learns that the buyer demands not only a good, but a cheap machine. The purchaser of electrical machinery is himself likely to be a manufacturer and realizes, at once, as some might not, that the lower interest charges on the smaller first cost may more than make up for the slightly greater operating expenses of the cheaper and possibly less efficient machine.

If it were thoroughly understood that design includes the consideration of cost of production as well as the excellence of operation, the statement, now much less frequently heard than formerly, that theory and practice do not agree, would have little meaning and would seldom be made. The cost end of the proposition is the one more often giving trouble to the practical designer.

It is understood that a book treating of the theory of machine design and construction cannot take into account all nor even many, of the various considerations of this nature which constantly come up in the factory. Below, a few of these considerations and instances where cost varies design will be taken up. These are selected rather at random and with the idea that they may be of interest to the student, not that they are new to the manufacturer or designing engineer.

One of the principal cost factors of manufacture which modifies the design from what theoretical considerations would otherwise dictate, is what we may call the "cost of stocking." The capital invested in material held in stock is lying idle, earning no interest. This demands that stocks, especially of unfinished—therefore unsaleable—parts to be kept as low as possible. Cheap production, however, demands manufacture in large quantities, for, to produce cheaply we need to use automatic machinery

which, with little attention, will rapidly turn out numbers of similar parts. But the setting up and adjusting of one of these machines for a particular job requires perhaps several hours work of a skilled mechanic, after which, with cheap labor, quantities of pieces may be run through.

Besides the expense of "setting up," which applies not only to automatic machinery as explained above, but also to the preparation for putting through any job of work, machine or hand, it must be remembered that any workman becomes more proficient after doing special one set of operations a number of times. On any new operation, however little may be the variation, he cannot immediately get into the swing of the work and make his best time. The more similar parts therefore, that the manufacturer uses, the less will be the expense of each part.

On the one hand, then, we require production in large quantities to reduce cost of manufacture, on the other the making of only sufficient numbers for immediate use. But enough stock must be carried to allow of uninterrupted turning out of the finished product and also to allow of the manufacture, within a reasonable time, of any particular machine called for. If, then, the manufacturer can make use of the same part in the construction of several different machines, he need not carry as large a reserve stock as if each machine took a different part, and he may, at the same time, gain the advantage of manufacturing the part in large quantities.

For example, except for the above considerations, a commutator of a length to give the necessary current capacity would be indicated for a given size of motor for 230 volts; for the same size motor for 500 volts a commutator possibly half as long; and for 115 volts one twice as long. The chances are, however, that all three motors will have a commutator long enough for 115 volts as it would be cheaper to use the extra material for all the other voltages than to go to the expense of separate patterns and of "stocking" three different commutators. This is especially true in view of the other necessary changes entailed. In the commutator of a large generator, on the other hand, the saving in copper would more than pay for the added expense of extra parts; and as the price of copper increases, the smaller the size becomes for which it would pay to use different commutators for each voltage. The number of machines of a given size put out also affects this. The larger the output, the more varieties is it economical to keep in stock, as can be seen from the following out of the arguments above.

To take another example; the less expense involved in making and using a single die and punching numbers of similar discs, may make it desirable to build two sizes of dynamos with the same diameter of armature when otherwise two slightly different diameters would have been used; the increased capacity of the larger machine being

secured in this case by making one armature longer than the other. Or, again, in transformers, the same core punchings and end plates may be used, simply building up a longer core for the greater output.

In connection with the cost of producing in small versus large quantities, it might not be out of the way to mention some difficulties arising from the specifying of special apparatus. Some consulting engineers are quite addicted to this vice. There is much that can be said in favor of not standardizing, as, that standardization tends to hinder "the advancement of the art." Still when the consulting engineer learns the cost of the special machine which is offered to meet his specifications, he usually finds that "the art" will after all allow him to use a standard article very nicely. One of the most frequent requirements of this nature is a special speed on a motor. This is often necessary, but a purchaser has been known to demand such a speed merely for the sake of using some old pulley on hand. Generally this is not an expensive change, provided too exact a speed be not required, but only the manufacturer can tell, for it may happen on a medium sized motor that such a change may require a special core punching. This means first, a new die at a cost of about $5.00; then the setting up of the punch press for this one armature—which may take longer than punching—at a cost, let us say, of a dollar more. If the standard motor is of such a size that a combination punch, punching all or several of the slots at once, is used, it will take many times longer to do the punching of this special speed motor, perhaps costing a further $3.00 extra. A combination punch for a single machine is of course out of the question. In the case supposed a special commutator will be required also, and the die for making the segments will cost another $5.00. It may require special brushes and brush holders. Then every process through the shop takes extra time from the drawing of the standard parts out of stock,—where it takes as long to make out the requisitions for one set of parts as for a hundred and nearly as long to get them out—through to the Testing Room, where special pulleys must be looked up and the test made singly. Not only does it take a man some little time to get hold of the new work, but he is more likely to "loaf on the job" and to put it off till convenient, because it is "special" and breaks in on the regular work. This feeling goes all the way from the Contract Department through the Engineering Department and Drafting Room to the last man handling the machine in the Testing Room. This increases the time it is in the shop. One might suppose that the extra expense would end with the actual extra cost of material and labor in all the departments, but one other expense, often overlooked, must be added. While this special motor is winding its slow way through the shop, it is taking up the space

and using the tools which might have been employed in the production of several "standard" machines, so that here again comes in the item of idle investment. Therefore, to come out even, the manufacturer must add to the actual shop cost and profit, a "burden" on all special apparatus. When all the above points are taken into consideration our buyer of the special speed motor, costing, for the standard speed, say $300.00, may well have added $50.00 to this price—rather a high price to pay for his pulley.

The sizes of sheet iron and steel obtainable will of course effect design as will the size of castings that can be made. The size of armature sheet steel may effect it from the cost side in various ways. The largest armature cannot of course be made from single punchings, but the ring must be built up of segments, which, for mechanical strength and magnetic continuity must overlap or break joints. To save waste of the sheet metal, which is rather expensive, the largest segment possible must be punched. This determines the number of segments in the ring of a given sized armature, which may be odd or even. This may also determine the number of spider arms, and if this number is odd, it will not be as easy to pull this armature off from the engine shaft, should this be necessary, on account of trouble in getting "drawing off bolts" to pull evenly. The number of segments will also, within limits, determine the number of slots, for the segments must lap, the slots must register and it is desirable to have as few different kinds of segments as possible to build up. In order to use only one kind of punching the break must come symmetrically with the slot and so the number of slots must be a multiple of the number of segments and breaks. The above requirements may make the dynamo slightly poorer as to efficiency or operation, but the difference is so slight as not to warrant the extra expense in holding to the design otherwise calculated—the buyer could not afford to pay the difference.

The very high price of copper of some time back has not been an unmitigated evil to the electrical industry. It has made it necessary to save every possible pound of copper, and from this necessity we have learned to ventilate our machines more effectively and to use our copper to better advantage. We might never have learned the lesson so well, had copper remained cheaper. This saving in copper has been almost always at the loss of efficiency, at least at full load, though it has allowed the use of smaller machines and helped in that way, and the smaller armatures and consequent smaller core losses have been utilized in certain cases to get higher efficiencies at light loads. But the copper losses are of course greater and more power is used up in blowing air through the machine. In engine type generators the engine is compelled to bear this latter loss, according to the rules now in general use.

These rather small increases in losses, however, are accompanied by very considerable reductions in first cost. So it appears that design may vary with the copper market. For connectors, brush holders, etc., iron and other metals have been used in place of copper and composition. In one case recently, where little brass tags were used to label machine terminals, it was found a saving to buy new stock of a cheaper material, punch and stamp new tags and scrap all the stock of old brass tags on hand. The price of the scrap brass was high enough to pay for the new material and extra labor and leave a profit.

Patents owned by other concerns must influence designs, the cost of royalties being ordinarily prohibitive. This is well understood by everyone, but is a point not often considered in texts where any form may be chosen for illustration. Generally this is a detriment, but sometimes leads to a substitute as good or even better.

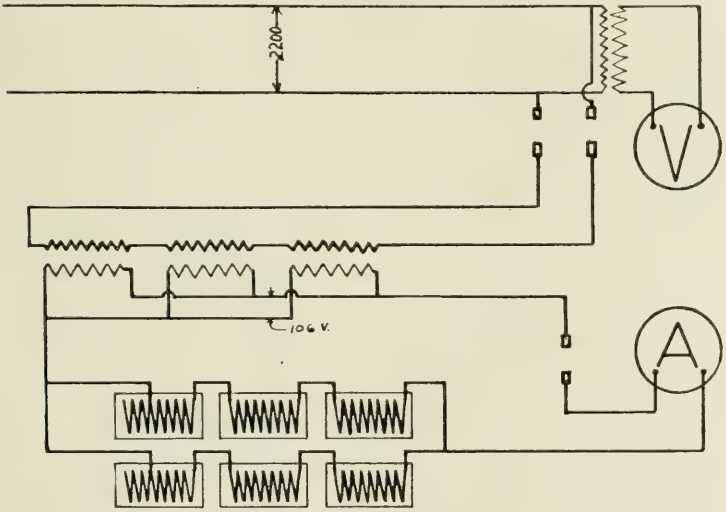
The designer must constantly have in mind an almost interminable list of little points of this kind. Most of them soon become a part of him so that he unconsciously looks out for them. The consulting engineer and the engineer engaged in drawing up specifications cannot be too careful in calling for changes in design unless they are sure the necessary extra expense involved is warranted.

METHOD OF DRYING TRANSFORMERS.

L. P. Brode, E. E., '11.

When transformers are shipped by freight to the Pacific Coast the windings absorb a large amount of moisture. This article is an account of the means used by the Los Angeles Pacific Co., of Los Angeles, California, to dry them:

The transformers are taken to the compartment which they are to occupy, and uncrated. If necessary, a tarpaulin is hung from the ceiling in front of the set in such a way as to keep out cold, and more especially, damp air. They are then connected to the current.



The diagram shown herewith gives the general scheme of connections. If the set being dried is in a station in operation, power is taken from the 2,200-volt station bus-bars. In one case, where a steam plant was to be replaced by a motor-generator set, 2,200 volts was sent from the main generating station, six or seven miles away, over the wires to be used later for the 15,000-volt transmission. In another case a station was being installed near the end of a line, and, although the trolley-wire was in place and the cars were running, the transmission line and direct-current feeders had not been completed. As the synchronous motor-generator set had been installed, direct current was supplied to the 600-volt side, and 2,200 volts taken off the synchronous machine acting as a generator. Since cars were running on the line, the trolley voltage

dropped sometimes as low as 300, and the speed of the set varied accordingly. It was impossible to keep the voltage on the transformers at 2,200. In this station the attendant was kept quite busy, but in the others all there was to do was to take readings, get the first whiff of scorching insulation, and change the resistance as necessary.

The resistance used to furnish a load is made up of a car-resistance grids connected in a series-parallel, enough being used to absorb from 15 to 300 amperes at about 105 volts. Centigrade thermometers are inserted as far as possible in the primary and secondary windings, and in the core of each transformer, and carefully packed with cotton waste. These are read every thirty minutes. Readings of the air temperature, and of the current in the secondary circuit, are also taken. A rise of one degree an hour is allowed at first, later decreased to a degree every three hours. At about 75 degrees in the windings, vapor commences to pass off, which may be rather alarming, as it smells of insulation. This continues up to about 85 degrees, reappearing occasionally after that according to the humidity of the air. The temperature is held for several days between 97 and 99 degrees in the hottest part, by alternately opening and closing the secondary circuit, when the transformers are placed in the tanks and the insulating oil is pumped in. The whole process takes from ten days to two weeks.

A table is given of the readings taken on a 450-kilowatt set of Stanley transformers, installed in the Ocean Park sub-station.

Thanks are due to Mr. C. W. Allen, Assistant Electrical Engineer of the Los Angeles-Pacific Co., for information kindly furnished.

			TRANS. No. 57869			TRANS. No. 57860			TRANS. No. 57861		
Time	Amps. in Secondary	Room Temp.	High Tension	Low Tension	Core	High Tension	Low Tension	Core	High Tension	Low Tension	Core
12:30 a m	210	24°C	55°C	56°C	28°C	56°C	58°C	28°C	57°C	56°C	29°C
3:30 a m	210	22	56	57	28	57	56	28	57	56	29
6:30 a m	205	24	56	56	28	59	58	28	58	57	28
9:30 a m	205	24	53	53	27	56	56	29	56	54	28
12:30 p m	220	24	54	54	28	56	56	29	56	55	29
3:30 p m	223	24	57	57	28	59	61	29	60	59	29
6:30 p m	230	25	58	58	28	60	62	29	61	60	29
9:30 p m	225	26	56	57	28	57	57	28	57	56	28
12:30 a m	225	25	58	59	28	59	60	28	65	61	28

Changed resistance at 11:45 a. m. O. K. 12:00 N. 3 banks of 3 boxes and 9 grids in series.

A. C. off at 7 p. m. On at 8:13 p. m.

A COMPARISON OF CARBON, METALLIZED CARBON AND TANTALUM FILAMENT LAMPS.

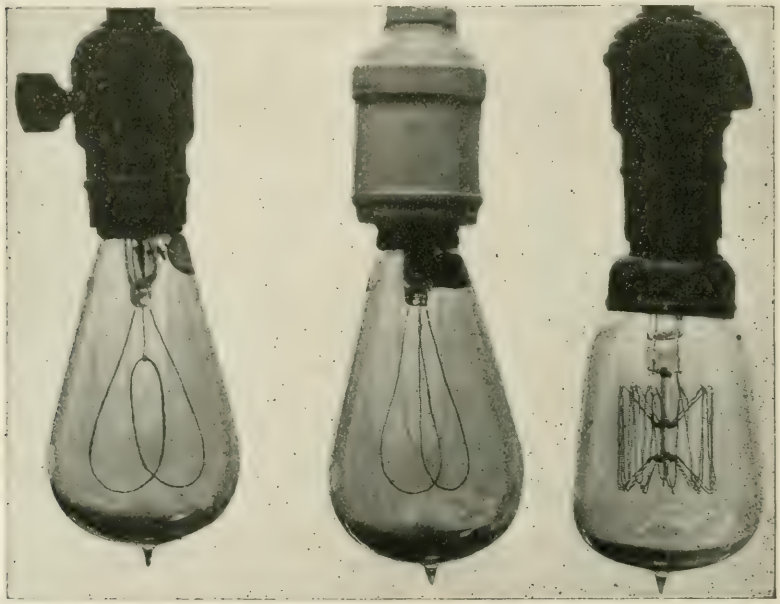
T. H. Amrine, B. S.

At the present time there are only three types of incandescent lamps having a wide enough commercial use to make them important factors in incandescent lighting. The first, and by far the most widely used is the familar carbon filament lamp, which in ordinary sizes gives an efficiency seldom exceeding 3.1 watts per candle power with an effective life of approximately 500 hours. The second type is also a carbon filament lamp, but the carbon, by the process through which it passes in manufacture, is given somewhat the characteristics of a metal and for this reason is called the metallized filament lamp. The manufacturers have claimed for it an efficiency of about 2.5 watts per mean horizontal candle power. In the third type the filament is made of the metal tantalum and there is claimed for it an efficiency of about 2 watts per candle.

This paper embodies in a very general way the condensed results of a series of comparative tests on these lamps conducted by the writer during the past year in the Electrical Laboratory for the Engineering Experiment Station. It was the purpose of these tests to bring out, if possible, the good points of each lamp together with any other facts in regard to them, that would help in the selection of the proper type of lamp for any particular purpose. Especial care was taken throughout the work to make the conditions under which the tests were conducted exactly the same for each type of lamp in order to have a fair basis of comparison between types. At the time these tests were started tungsten lamps could not be purchased on the market and for this reason were not included in the tests. In the matter of current consumption, life and candle power maintenance these lamps seem much superior to the three kinds tested. They have an efficiency of about 1 watt per candle power and a life of a 1,000 hours with a decrease of only 10 per cent in candle power. However, they are open to several objections. The filament is very fragile so that they require careful handling. In a shipment of twelve tungsten lamps received by the Department of Electrical Engineering some time ago five filaments were broken in transit, notwithstanding very careful packing. Moreover, the tungsten lamps cannot be had in sizes less than 40 candle power and they must be burned in approximately a pendant position.

The lamps chosen for the test were selected from a lot of 100 of each type of lamp. These were bought directly from the manufacturers, a well know and reliable incandescent lamp company. The carbon lamp was of the ordinary, single loop filament type

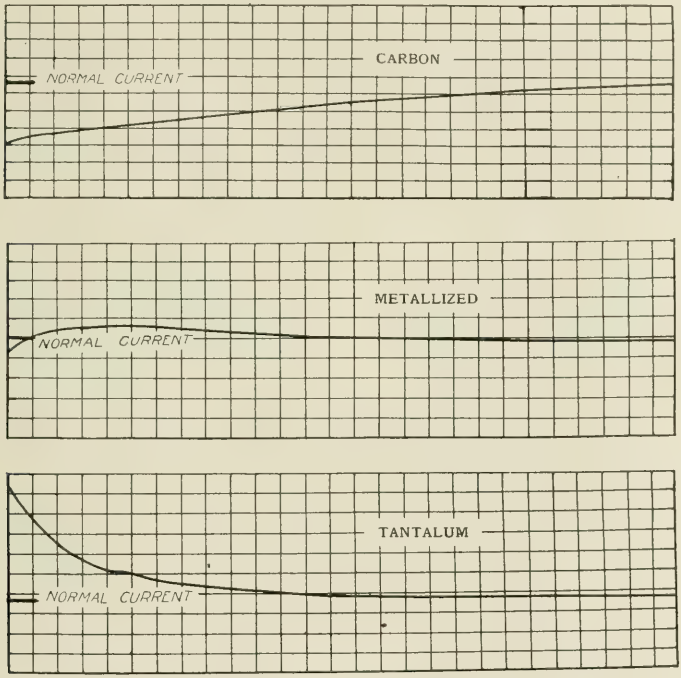
and was rated at 25 candle power at 110 volts with an efficiency of 3.1 watts per candle. The metallized lamp had a double filament and was rated at 50 watts and 110 volts. The tantalum lamp had a filament mounted in the usual well-known, zigzag fashion upon supporting spires. It had a rating of 22 candle power at 110 volts. Below is given a photograph showing the three types of lamps.



The three types of lamps differ radically in their temperature characteristics. The carbon filament has a negative temperature coefficient, that is, its resistance decreases as the temperature increases. On the other hand, due to the treatment which it has undergone in manufacture, the metallized carbon filament has a positive temperature coefficient similar to the metals when in the incandescent stage. When cool, however, it, too, has a negative coefficient. The tantalum filament, being of metal, has of course a positive temperature coefficient.

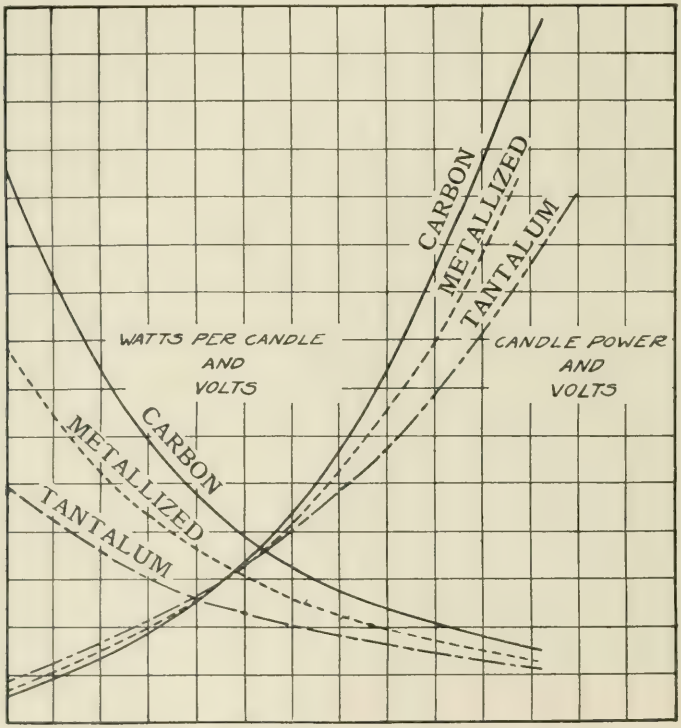
As a result of the positive coefficients of the metallized and tantalum filaments these lamps flash up to full incandescence much more quickly than the carbon lamp. When the current is turned on, the filament, being cold, has a low resistance and there is a rush of current considerably above normal. This excessive current is rapidly cut down, due to the increase in resistance as the lamp reaches incandescence. The carbon lamp, having the greatest resist-

ance when cold allows but a comparatively small current to pass at first, but gradually allows it to increase as the resistance becomes less. This is beautifully shown by the oscillograms of the rise of current in the three lamps shown in Fig. 2. With the carbon lamp it is seen that the current rises almost instantly to about .35 ampere and then rises in approximately a straight line to the full steady value of current in about .26 second. With the metallized lamp the current rises at once to about .45 ampere, almost the full



steady current, then increases to a maximum value of .55 ampere in approximately .05 second, indicating a negative temperature coefficient at the lower temperatures. It then decreases gradually to the normal steady value in about .16 second. The curve for the tantalum lamp indicates that a rush of current takes place as soon as the circuit is closed, reaching a maximum of about .93 ampere, almost three times the full steady current, practically instantaneously, and then drops rapidly to normal. This rush of current in the tantalum lamp will probably require that some precautions be observed in switching feeders heavily loaded with tantalum lamps on the generator. The heavy excess current at the first instant might easily be sufficient to damage the machine.

The candle power-voltage characteristic curves in Fig. 3 also show important differences in the three types of filaments. At 80 volts the carbon filament starts at the lowest value for the three lamps and rises rapidly until at normal voltage and above it has the greatest candle-power. The tantalum filament takes the highest position at the 80 volt point and increases more gradually until at normal voltage and above, it has the lowest candle power. The metallized filament curve takes an intermediate position. The equa-



tions for these curves obtained by the method of least squares from the experimental data are:

For the carbon lamp

$$C.\ P. = 143.5 \times 10^{-13}\ E^{5.97}$$

For the metallized lamp

$$C.\ P. = 50.7 \times 10^{-11}\ E^{5.20}$$

For the tantalum lamp

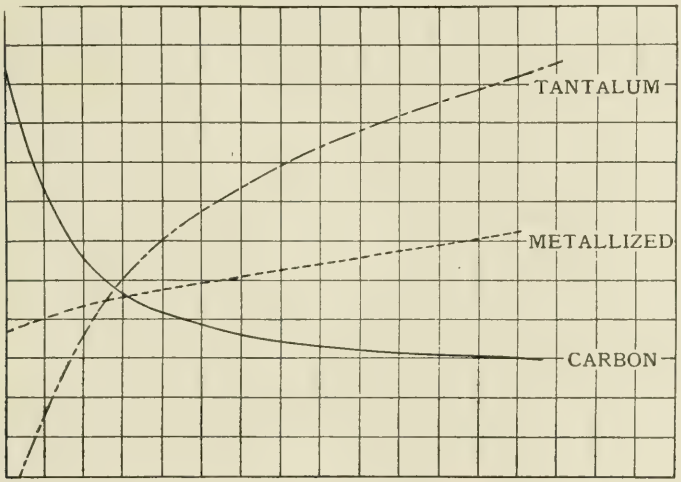
$$C.\ P. = 166.4 \times 10^{-10}\ E^{4.45}$$

Below is shown the table exhibiting the change in candle power for an increase of 5 per cent and for a decrease of 5 per cent in voltage from the normal.

TABLE I.

Lamp	C. P. Increase for 5% Voltage Increase	C. P. Decrease for 5% Voltage Decrease
Carbon.....	7.3 C. P. or 33.2%	6.8 C. P. or 31.0%
Metallized.....	5.6 C. P. or 25.7%	5.8 C. P. or 27.6%
Tantalum.....	4.4 C. P. or 22.0%	4.8 C. P. or 24.0%

The change in efficiency or watts per candle are also shown in figure 3, indicating a wide difference in favor of the tantalum lamp throughout the range of voltage.



The curves showing the change of resistance with the voltage, (Fig. 4) indicate that the tantalum and metallized filaments tend to regulate for constant current when in the incandescent stage. In these filaments the resistance rises with the voltage. Hence on a poorly regulated circuit, when there is an increase in pressure, the resistance of the filament becomes greater due to the increase in temperature. This prevents such a great rise in current and candle power. With the carbon lamp the change in resistance is such that it tends to aggravate the effects of a fluctuating voltage. When the voltage increases there is a decrease in resistance. This decrease in resistance adds to the change in current naturally brought about by the increase in pressure and the result is a very rapid change in current and candle power. For a decrease in voltage, of course, the reverse is true; a drop in voltage causing a rise in resistance,

the change in both of them being in the direction to decrease the current and candle power.

Life tests were made of the three kinds of lamps under two conditions. Ten lamps of each kind were put through the life and efficiency tests upon a steady, well-regulated voltage supplied by a storage battery floating across nearly constant potential mains. The maximum variation in voltage was probably not more than one volt and during the greater portion of the time the voltage was as nearly correct as the portable voltmeter used would indicate. This was designated "Condition A" and represents the best conditions under which the lamps would ever be operated in practice. The same number of lamps were operated under adverse conditions. A badly fluctuating alternating current was supplied the lamps and there was considerable vibration. The condition, designated "Condition B," is representative of very bad operating conditions.

As a summary of the tests the results from the three types of lamps will be compared with respect to the following eight considerations which determine the choice of an incandescent lamp.

1. Efficiency.
2. Cost of operation.
3. Maintenance of C. P. and efficiency.
4. Life.
5. Quality of light.
6. Distribution of light.
7. Susceptibility to voltage variations.
8. Ability to withstand rough usage.

Efficiency. In the matter of efficiency alone these tests as well as all other tests which have been made with these lamps, show conclusively that the metallized lamp is much superior to the carbon and that the tantalum is much superior to the metallized. The difference between 3.1 watts per candle and 2.0 watts per candle, about 28 per cent, is sufficient to outweigh almost all other considerations. It means that a 20 candle power metallized or a 22.5 candle power tantalum lamp can be operated with the same amount of energy as a 16 candle carbon lamp. It means that a power plant which is running with a heavy overload of carbon lamps would, if the carbon lamps were exchanged for the same candle power of the newer lamps be operating at about normal load with the consequent advantages. In the same way, they provide a means of lightening overloaded feeders and that without any decrease in the candle power of light furnished.

Cost of Operation. The curves of figures 5 and 6 show that upon well regulated circuits each type has a field of its own within which it is the most economical to use. For very low costs of power the carbon lamp gives the best economy. Hence, particularly for persons who generate their own current it would pay to change

from the carbon to the higher efficiency lamps, because in this case, either the cost of power is low or else the fuel bill, the only place where there would be a saving by using high efficiency lights, is not large compared with other expenses such as attendance charges, taxes and interest. When the cost of energy is high as it is in most cities the tantalum lamp would be the best to use. The metallized lamp seems to be restricted to rather narrow limits of power cost and to good operating conditions.

The newer types of lamps would have a great field in lighting railroad trains and steam ships, where the cost of power is always high, if the filaments were robust enough to withstand the shocks and vibrations that are usually present. It seems that it might be possible and advisable for manufacturers to develop series tantalum and metallized lamps for this service. The filaments that would be used in a series lamp would, no doubt, be strong enough to withstand the vibrations and their economy of current consumption would make them much preferable to the carbon lamp.

Maintenance of Candle Power and Efficiency. In regard to maintaining candle power and efficiency the newer lamps make by far the best showing, the two being almost equal in this respect. The metallized and tantalum lamps have a drop of, respectively, 20 and 19 per cent in candle power in 1,000 hours under condition A, while the carbon lamp drops 32 per cent in the same time and under the same conditions. The change in efficiency for the three lamps is in about the same proportion.

Life. Comparing the lamps upon the basis of average life to 80 per cent of the original candle power, which is standard for the carbon lamp, the following results are obtained:

TABLE II.

	LIFE IN HOURS TO 80% OF ORIGINAL C.P.		
CONDITION	CARBON	METALLIZED	TANTALUM
A	400	780	820
B	225	350	350

This method of comparison is, if anything, unfair to the higher efficiency lamps, because, owing to their higher first cost the "smashing point" should be after the lamps have reached a candle power considerably less than 80 per cent of the original. It serves, however, to show the superiority of the newer lamps in this respect.

Quality of Light. The quality of the light from the metallized and tantalum lamps is much the same, both having a light considerably whiter, softer and more pleasing to the eyes than the carbon lamp. Giving a whiter light, the newer lamps show more nearly the true values of colors than the carbon lamp and hence are

superior for lighting dry goods and clothing stores, art and picture galleries and other places in which colors must be judged.

The intrinsic brilliancy of the three sorts of filaments are approximately

Carbon 140 C. P. per sq. in. of filament area.
Tantalum 165 C. P. per sq. in. of filament area.
Metallized 190 C. P. per sq. in. of filament area.

On account of the great intrinsic brightness of the newer types of filaments and particularly of the metallized it is not advisable to use these lamps for interior lighting, when they are placed low enough so as to be in the line of vision, unless they are provided with ground glass or opal globes.

Distribution of Light. The distribution of the carbon and metallized lamps are so nearly identical as to admit of little choice between them in this particular. The tantalum lamp differs from these in having a low tip candle power, which is a point in its favor when used with reflectors. For use with reflecting globes the most efficient lamp for any given watt per candle consumption would be one with a long straight filament mounted vertically. This sort of an arrangement gives the condition where the minimum proportion of light is radiated downward and upward, but gives a distribution which can be easily changed to suit the requirements by means of reflectors, and is such that the minimum light is lost in the base. Getting a downward distribution by placing the greater portion of the filament horizontal as has been done in many of the "downward light" lamps on the market is an efficient method. It is true that these lamps throw the maximum of their intensity further from the horizontal than an ordinary lamp, but in so doing just as much light is thrown upward where it is mostly lost in the base and on the ceiling by absorption and improper reflection. To get light where it is needed, and to do so most efficiently, is accomplished by mounting the filament so that as nearly as possible the entire length of it is parallel to the axis of the lamp and then using good reflectors. The tantalum lamp meets very well this requirement as shown by the low candle power at angles even up to 30° from the tip. Since the filament is symmetrical there must also be a radiation of low intensity toward the base of the lamp. Now near the base all light that has its course changed downward by reflectors must strike the reflector at a large angle which, of course, is a condition that favors absorption losses. On account of the lower radiation of the tantalum lamp in these unfavorable directions it is superior to the other two lamps if reflectors are used. When the lamps are used bare the carbon and metallized lamps give a greater candle power downward where it is generally needed than does the tantalum lamp.

Susceptibility to Voltage Variation. Table 2 gives a comparison of the way these lamps act in regard to the very important point of susceptibility to voltage variation. For use upon poorly regulated feeders or at the end of long feeders that are sometimes heavily loaded, the metallized and tantalum lamps will make a much more uniform and pleasing light than the sensitive carbon lamp.

Ability to Withstand Rough Usage. It is in this particular that the carbon lamp stands supreme. Long experience in making them has enabled the manufacturers to make a carbon filament that will withstand almost any reasonable usage. The filament of the former are so fine that jars such as would be caused by screwing the lamp into or out of the socket sometimes makes the two halves of the filament cross each other near the top. This short circuits about one-third of the filament, and if the current is turned on the lamp burns at a very high candle power. This, of course, greatly reduces the life of the lamp if the filaments are not separated. They may be shaken apart by tapping the lamp, but usually not before the filament has been materially weakened.

Conclusion. From the study of these lamps it appears that the carbon filament and the tantalum filament can cover adequately all the phases of incandescent lighting that are now covered by the three types. For lower power costs, for rough and unusual uses, and for small candle power units the carbon lamp is the best and often the only one that can be used. For higher costs of power upon poorly regulated circuits and for lightening the load upon overloaded stations the tantalum lamp is the best. It is not recommended by the manufacturers for use upon alternating current circuits yet the results obtained show that although it does not do so well upon alternating current as it does upon direct, it still gives better economy for the higher costs of power than the carbon lamp. The principle fault of the metallized lamp is that of mechanical weakness, which probably does not exist in the larger sizes where a heavier filament is used, so that for units of 40 or 50 candle power and above, this type of lamp might be very satisfactory in this respect.

DECORATIVE LIGHTING.

H. E. Page, E. E., '08.

It is hard to say when the incandescent light was first used as a decorative feature, but it first came into prominence at the Chicago World's Fair and reached its zenith at the World's Fair at St. Louis, where the beauty and artistic display of the electrical decorations surpassed anything ever seen. One could almost imagine himself in Fairyland as he sat in a launch in the Main Basin and watched the alternating red, white and blue lights on the buildings, and the concealed lights under the Cascades.

Thousands of dollars were spent on the electrical decorations, and it was money well spent, for without it the grounds at night would have lost half the fascination that attracted thousands of people from all over the United States. A radical change was made in the placing of the thousands of incandescent lamps used for decorative purposes. At Chicago the lights were placed on the various buildings so as to outline the entire structures and bring them into prominence, but at St. Louis, the lights were concealed, and merely the reflection of the light was shown, bringing the beauty of the architecture into prominence as well as the outline of the buildings.

Decorative lighting with the incandescent lamp has become a permanent thing, is used everywhere in public and private buildings, and even in the home, and is really a profession in itself. Many large architectural firms having specialists in that line constantly employed. Decorative lighting in the home can be used with excellent effect, doing away with the ugly chandelier hanging in the middle of the room, and an artistic cluster in the ceiling used in its place; using table lights with floor plugs and convenient wall lights.

In public buildings the lights are generally placed with an eye for decorative effect as well as for general lighting. The beauty of a large building with a dome or arches is enhanced 50% by the artistic placing of the incandescent lamp, and when the current is turned on the lights on the dome of our own Auditorium it will improve the external appearance at night greatly.

Although it is doubtful whether electrical sign illumination would be classed as a decorative lighting, it is worthy of a passing remark. Perhaps in no other cities in the world are the incandescent lamps used for sign illumination as extensively as in Chicago and New York City. Go to the top of the Masonic Temple in Chicago and see the enormous amount of money spent along this line; looking one way you will see a sign, ingenious in its construction, calling attention to a certain brand of clothes or shoes, another to some liquid refreshment that made Milwaukee famous; and in

New York City at night from Central Park to the Battery, Broadway is a glare of electrical decorations, that has earned for it, the sobriquet, "The Great White Way."

The up to date merchant uses the incandescent lamp in his store and in his show windows, many attractive decorations being used to call attention to goods displayed, and even the church Christmas tree has placed in its branches tiny incandescent lamps, instead of the time honored wax candles that caused so many fires. Marshall Field of Chicago, during their fall opening spent $9,000 on their electrical as well as their general decorations, and it even made the Chicago public open its eyes and admire it, much as they see of this sort of thing.

During the last few years most of our formal balls at the Armory have been made more attractive by the use of decorative lighting and special effects, and although, from the interior construction of the building it is hard to get good results, some very pretty effects are had.

It appears that the decorative idea in lighting can be used to good advantage on our public street lighting systems where the beauty of our paved streets would be greatly improved by artistic street lights and poles in place of the ugly affairs that now grace our principal thoroughfares.

In many ways decorative lighting can be used to improve the appearance of almost any building and combine the practical with the beautiful. If the new tantalum lamp proves a commercial success the economy of its use will make the incandescent lamp more popular than ever.

ELECTRICITY IN THE MODERN THEATER.

J. M. Bateman, E. E., '08.

It does not take a great stretch of memory to carry us back to the early days of modern stage and theatrical lighting, back to the times when the gas-footlights with their flickering glimmer and ghastly shadow made the livest-tinted grease paints seem "dead." and gave the heavy man's act an impressiveness not always in the lines; when the gas "borders," wire guarded though they were, gave the stage manager chills and fever every time the draft blew a hanging drapery against them,—there were no underwriter's rules in those days; and we can remember too, after a dark scene or change, when the house operator had cut out his main valves and was depending upon the by-passes to keep the jets barely alight, how a sudden breath of air through the house would extinguish everything, and the candle-boy, with his long lighter, would "put on" a specialty not included in the regular program.

But all this has changed with the advent of the electric light. The smoky, wavering, uncertain jets with their guards, the long pipe runs and the leaky hose connections that every grip and stage hand seemed in duty bound to collide with and loosen, the houseman's closet, filled with massive valves and cut-offs, tees, cross-connections and by-passes; even the long handled lighters were long since consigned to the scrap heap, and electricity now reigns supreme in the land of stagedom.

The uses that the electric current can be put to in the staging of the modern theatrical production or the equipment of the twentieth century play-house are many and varied. The supplying of the energy for the telephone systems connecting the several parts of the house, the lighting, inside and out, back stage and in front, by thousands of incandescents, the producing of the hundred and more effects made possible by the cunning of the master-man and the versatility of the servant, the manipulation of the great five-ton steel curtains by a touch of the hand—all this is but child's play in this electrical age.

The theater as is generally known is divided into two sections, the stage,which includes all that portion to the rear of the proscenium wall or the foot-light line, and the "house," comprising the auditorium, foyer, lounging rooms, offices and lobby, and each section has a system of lighting peculiar to itself, the whole however being subdivided again into three classes of illumination—incandescent, arc, and emergency lighting. The regular lighting of the "house" presents a simple problem for the illuminating engineer or architect, the placing of the lamps and their most satisfactory distribution being largely a matter of choice and artistic taste. The emergency

lighting on the other hand is controlled by rules formulated by the municipal council or the local board of underwriters and these rules must be obeyed to the letter. One eight candle power lamp is required for every forty square feet of floor space, each and every exit must be marked by a red light and all emergency and exit circuits are wired separate and distinct from other lighting and power lines, as well as having an entirely separate source of supply or service from the ordinary mains. It may be remarked in passing that it is customary to provide a sperm lamp or gas jet to indicate the exits as a supplement to the electrics.

Since the Iroquois disaster in Chicago, municipal councils, fire underwriters, and architects generally have made a careful study of the theatrical problem with the result that conduit or iron pipe has been almost universally adopted all over the country, as the safest and best means of wire protection, and all lines; lighting power, telephone, and bell circuits are now placed in this metal tubing. The main distributing point for all circuits is the stage switchboard which is always set in what is known in stage parlance as the "first entrance," on the right of the proscenium opening. Switchboards may be floor-boards, which are those manipulated by the operator standing on the stage floor, or gallery boards, set ten to twelve feet above the floor and worked from a narrow platform or gallery, the particular style or type depending upon the personal preference of the builder. The main board is usually made up of several panels, more or less elaborately mounted, one for the house circuits, another for the stage and sometimes a third fitted up with extra switches, fire alarm pulls, curtain calls, and the like. In general the plan of electrical distribution is comparatively simple. Direct current, where ever available, is always used for theatrical work, inasmuch as it causes no objectionable humming in iron-core coil-wound apparatus, as does the alternating current, and it has also been found to give better service in the operation of arc "spots" and "calcium" lamps in scenic effects. A three wire service of ample circular millage, in the larger houses a 1,500 ampere load per side not being uncommon, is brought either from the private plant of the theater or from the supply company's main entering the building in the basement, into a main line triple-pole, quick-break switch located usually on the house panel. This controls every circuit in the theater except the emergency and exit lights, and is only used in case of accident or extreme necessity. The service bus divides and feeds three smaller triple-pole switches, controlling respectively all house circuits, all stage circuits, and all stage "pocket" or plug circuits. The house-bus is the distributing center for the house lights, and through various double-pole switches different portions of the auditorium, foyer, lobby, and green rooms are controlled.

The stage panel is somewhat more complicated in its make-up

than that of the house, and is designed for heavier loads, as well as for harder and more various service. Stage lighting as a whole is accomplished by a number of methods and means. Of these the more important are the "foots," "borders," "bunches," "strips," proscenium lights, and auxiliary or "dark change" lamps. The "foots" or footlights are made up of several rows of incandescent lamps, tipped at a slight angle, and arranged within a trough reflector, cut below the floor of the stage, or apron, at such a depth as to allow the hood of the trough to show but slightly above the level and refract the greater portion of the light toward the stage at an angle of about thirty degrees. Three separate color circuits are used, white, blue, and red or amber, being the usual variations, and each circuit is carried back to the switchboard.

The border lights, so named from their hanging position among the scenic borders or draperies, are built up of light sheet-iron troughs, extending the width of the stage exclusive of the wings, and suspended inverted by a set of lines from the gridiron above. The lamps are arranged as in the case of the "foots," the three-color scheme being followed throughout, with the whites predominating. Connections to the borders, which are necessarily lowered or raised as the scene may require, are made by heavy flexible hemp-protected cables, looping directly from the gridiron along the center line carrying the border, these cables in turn being connected to the leads from the switchboard.

The "foots" and "borders" form the essential elements in stage lighting, the other features being but auxiliary. The proscenium lights are those arranged in vertical rows on either side of the proscenium arch, just within the curtain line, and are used to supplement the "foots." The "dark change" circuit is one but rarely found in even the most up-to-date theatres, yet it is a valuable adjunct to any equipment. Around the outside of the proscenium arch, facing the auditorium, and niched-in, flush with the face of the wall, is set a row of high-candle-power incandescents, backed by powerful reflectors in such a way as to present a dazzling light to the audience. With this circuit cut-in, the stage itself is practically invisible from the house, and a dark change without dropping the curtain may readily be effected.

"Strips" and "bunches" are portable methods of illumination, and as such are adaptable to all circumstances and settings. The former consists of a wooden batten, ranging in length as necessity may require from three to fifteen feet, and carrying lamp receptacles screwed to it at regular intervals of about eighteen inches. The wires are cleated or otherwise held in place upon the batten, and the whole is protected by a sheet metal or tin casing, which is perforated to allow the base of the lamps to project into the receptacles. A heavy insulated flexible cable, permanently fastened at one end

of the strip, carries a connecting plug at its other extremity, and in this way may be plugged-in either at one of the stage floor pockets, or to a plugging box temporarily connected to the switchboard.

The "bunch" light consists of an upright standard, built of a solid substantial base, a length of ¾" pipe about five feet long and a hood reflector with a bunch or cluster of incandescent lamps arranged about its arc in such a way as to project the light in any desired direction. The combination is particularly adapted for setting in the wings to illuminate dark entrances and scene backings where the borders are insufficient. Its method of connection to the circuit is by cable and plug to the floor pockets. These pockets are openings about 6 by 9 by 12 inches cut in the floor at regular intervals up and down the stage just within the wings or outside the actual working portion of the floor. They are covered by steel-hinged lids and fitted up with several plugging receptacles to which connection is made to the various portable devices used during any performance. Floor pocket receptacles are of two types or rather are used for two purposes, incandescent work as has already been described under the heading of "bunches," "strips," etc., and "arc" effects.

Although incandescent lamps are suitable for ordinary illumination where a great glare of light is not desired, there are numerous scenes and acts where striking contrasts and strong lighting is essential and the arc is here used to excellent advantage. Two types of arcs are used—the open box or "calcium," and the "spot," each having its own field of utility. Both are built upon the same principle, in that the carbon arc is used for the source of illumination, the difference being that the "spot" is entirely hooded, a lens transmitting the light, and, as its name implies, concentrating it upon a comparatively small spot or area, while the calcium is a rectangular box, open on one side, its white enameled interior refracting the light over a large surface. All stage arcs are hand fed, no automatic carbon feeding devices being employed, and both types are mounted upon pipe standards, the series resistance being wound upon the bases and enclosed type knife switch device placed upon the upright beneath the lamp itself. All lamp connecting-leads are asbestos insulated to protect them from the heat of the arc and the resistance. The carbons and feeding mechanism are entirely enclosed by a sheet metal case provided with a red-glazed door, allowing access to the interior, the feed being actuated by a knob projecting from the rear of the box. The ordinary calcium or spot light requires from fifteen to eighteen amperes and working at 110 volts draws an arc varying from one-fourth to nine-sixteenths inches in length. The color schemes in the case of the "box" are worked by means of gelatine color frames, slipped into run-ways at the front of the lamp, while the "spot" is usually fitted with a "boomerang," con-

sisting of a light tin disc about twenty inches in diameter, cut with a number of six-inch openings, in which are placed the different gelatine colors. The whole is pivoted above the lens of the lamp, and is rotated vertically and parallel to it. It may be stopped at any point, thus giving any color effect desired.

The arcs are supplied with cables and plugged into the floor pockets, as are the incandescents, separate receptacles, however, being used, as the former circuits must be fused considerably higher than the latter.

To return to the switchboard: It will be apparent that the stage panel must be equipped so that any combination of lights of any desired brilliancy may be secured. One of the most important devices in this connection is the "dimmer," which although simple in its action is most effective, being capable of varying the candle-power of any circuit, from full brightness to mere redness. It consists essentially of a variable resistance, mounted, usually, back of the switchboard and actuated by handles on its face. Each main circuits of the "foots," "borders," "bunch" pockets and proscenium lights is cut in through a single dimmer, and the handles are so arranged on the board that each may be manipulated separately, or any number may be worked in multiple. To secure the flexibility of control, which is essential in the high class theatrical productions, the stage panel must be carefully designed with reference to speed and adaptability of manipulation. The position of the switches must be such that the electrician can not only obtain a wide range of results, but also "play" his board readily in the dark, and under all circumstances. The stage main switch, connected directly from the service bus bars, feeds into the stage bus, and thence to the numerous circuits, the various smaller switches being placed conveniently near the center of the panel, as their use necessitates. The "borders," of which there are from four to six, with three color circuits in each, are collectively fed from the stage bus, through a double throw main, each circuit then being controlled by its own single throw switch. The double throw feature is used in all of the stage main-switches, one side being connected to the stage bus, while the other is cut-in directly on the service bus. In this way it is possible to secure selective control of any portion of the "foots," "borders," or pockets. For instance, a light plot may read: "At cue, pull all lights but red spot in third entrance." The electrician or switchboard operator in getting ready for the change reverses the double throw switches across to the stage bus side, except the pocket in the third entrance, which is left "cut in straight" to the service bus. Then at the cue given by the show manager, he pulls the stage main and everything is darkened except the single "spot," which is left burning. The "foots" are also connected through the main switch so that

they may be thrown together or separately, or may be raised and lowered on the dimmers.

All circuits are protected, usually by cartridge-type fuses on face of the board, although fuse links in enclosed cabinets above or below the panels are allowable, and are used in many instances.

The purposes for which the electrical power may be used in a theatre are many. The massive steel curtain is automatically operated by a specially controlled motor or pair of motors in such a way that it is raised and lowered without a jar or a tremor. In those houses employing the hydraulic lift the water pressure is maintained by motor connected pumps, and in the same way the sewage pumps in buildings whose basements are below the street intake level, the scenery elevators and hoists, the ventilating fans, are motor-driven. Even the great emergency vents in the theatre roof, a hundred feet above the stage, are dependent upon the current for their action through the agency of powerful electro-magnets, which release the fastenings and allow the glazed panels to open. Intercommunicating telephones from the box office to all parts of the theatre; electric heaters, electric cooling fans throughout the auditorium, electric curling irons in the dressing rooms, electric messenger service, electric fire calls, everywhere efficient, reliable, constant, electricity is used to advantage.

The effects produced by electricity are varied, and thunder storms as realistic as a genuine elemental outburst are too common a specialty to cause comment to present-day theatre audiences. The lightning, which may be of the sheet or the "zig-zag" variety, is produced by means of a make-and-break contact between a heavy carbon and a coarse rasp or file. An iron resistance box is connected in series with a cable, tapped in at the floor pockets, the two terminals of the circuit being soldered to a carbon holder and the file, both of which are fitted with insulating handles. The operator strikes the two together at intervals, and the result is a blinding flash of lightning. The "forked" effect is accomplished by means of zig-zag openings in dark backings or cloud "drops," which when illuminated from the rear give a striking resemblance to an actual discharge of atmospheric electricity. Thunder, although not an electrical product, is ordinarily made by the electrician's assistant. It is done by violently shaking the so-called "thunder-sheet," which is a large section of sheet metal, usually iron or tin, suspended from the rigging loft. More conveniently, however, if the operator is experienced, it may be produced by beating a bass drum. The old method, now but seldom used, is that of rolling heavy iron balls across the fly floor, or running them down troughs or chutes. The objection to this idea—it may be remarked—has been that the balls often break away from the operator and wreck havoc by falling

to the stage floor thirty feet below, or in other ways causing trouble.

Wind, rain, and snow are purely mechanical effects, dependent however in many instances upon electrical action. The wind machine consists of a cleated-circumference drum revolved against a strip of heavy canvas held in tension, the apparent velocity of the wind depending directly upon the speed of rotation. This may be motor driven, but it is usually turned by a crank. The sound of falling rain is closely imitated by dropping peas on a drum head, and where a visible rain storm is called for, as in the famous shower scene in "David Harum," an iron pipe perforated with a single row of pin holes along its lower side is hung from a set of lines near the front of the stage, and out of sight of the audience, and is connected with the nearest water tap by a hose line. The rain is caught on the stage floor in an oil cloth tarpaulin. Since the pipe perforations are very small and a stage rain storm is usually brief, a "shower" does not usually require more than a few pails of water.

The best example of the artificial snow storm is found in that universal favorite, "Way Down East." Here electricity aids the mechanical in out-rivaling nature. The snow-bag, a patented device for uniformly dropping the paper "snow," is swung in the borders, in a way similar to the rain pipe. To secure the blizzard effect a battery of electric fans mounted one above the other on a movable platform is set up in the wings. The draft supplied in this way is sufficient to blow the snow particles across the stage, and used in conjunction with the wind machine, it produces an effect that is, to say the least, true to life.

A number of methods of obtaining moonlight or moon effects are used with various degrees of realism. The most common is the rising full moon, produced by a tin pan fitted with several incandescent lamps, and hug vertically into the opening against the rear of a "drop" or canvas scene by a line wound on a clockwork-actuated drum. The "drop," usually a mountain scene, is transparent enough to show this large ball of yellow light through its paint. As the cord is wound on the drum the moon appears to rise out of the hills, and at the same moment the electrician raises the amber "foots" and borders on the "dimmer," giving the scene the yellow, hazy light of a summer moonlight evening. In conjunction with this effect, a very pretty fire-fly specialty is worked out by tiny miniature battery lamps, suspended on invisible wire threads from the borders, contact to each being made at the will of the operator.

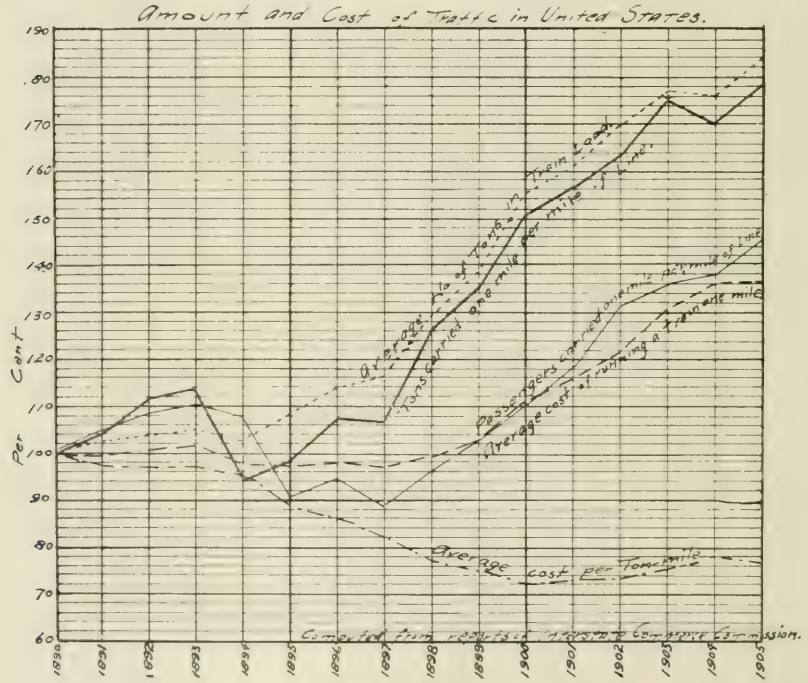
The house electrician in a large metropolitan theatre, drawing a salary of twenty to fifty dollars a week, must be not only a thoroughly practical man, but must have a clear head, a quick hand, and a resourceful personality. He is responsible for everything electrical about the house, from the talking sign in the street to the

proper repair of the lamp socket in the chorus-girl's dressing room. He must be able to manipulate the switches in the dark or with his eyes shut, and to give any possible combination of lighting without an instant's thought or hesitation. When a new production comes in, it is his duty to see that all electrical apparatus is sufficiently up-to-date to be passable by his city ordinances, and then he must send for the city theatrical inspector and secure an official permit for its use. He must keep in working order every unit of the great electrical system, from the curtain bell, or warning light to the motors used for the operation of the steel curtain. During the performance the house electrician is directly responsible for any trouble arising in any way from electrical causes. He must see that each calcium or spot light is provided with a reliable man to operate it, and besides manipulating the main switchboard he must be ready at an instant's notice to change the setting as the show manager may dictate. At the close of the scene or act, he must superintend the rapid "striking" of all electrical paraphernalia, its removal from the path of the stage hands, who follow immediately, and he must have his effects all ready to "hang" or "set" the moment that the following setting is completed. It has well been said that "there are no fortunes made on the stage," and the way of the stage worker, whether he be actor or "grip," or electrician, removed from the romanticism of the glaring calcium and the footlights, is a hard one.

SOME PHASES OF THE ECONOMICS OF RAILWAY LOCATION.

R. B. Slippy, C. E.

The engineering profession has made remarkable advances in the past 50 years. The professions of Civil Engineering, Mechanical Engineering, and Electrical Engineering have proceeded from a single one, and from each of these are growing branches which now engage large numbers of men in their pursuit. Not the least of these is Railway Location.



To call to mind the great and complicated network of railways covering the United States, upon which nearly all of our commercial life depends, is to realize the importance of the work of the locating engineer. We may at the same time be impelled to wonder how many more new railways will be built; and we must conclude that the day is not far distant, when new location work will be very slight. This does not mean that the era of the locating engineer is past, though we may adopt a more descriptive title for

the work he still has to do. So wisely have the railways been located in the past, that they have developed their tributary country to such an extent that the need has come for extensive revision. The country has grown and the railroads have had to grow with it to meet the demands for a greater carrying capacity and for cheaper transportation. Therefore the locating engineer's work in the future will be that of railway revision, and we may well call him the revision engineer.

Both the locating engineer and the revision engineer will be governed by the same principles of economics, though the points of view are somewhat different. On new location, the engineer may not have very accurate information as to the effect on the cost of operation over heavier grades, rise and fall, greater distance, and great curvature. He is usually compelled to rely on information obtained from observations on roads on the cost of operation of excess grades, rise and fall, distance and curvature, except as obtained from observations on roads already built and operating under perhaps greatly dissimilar conditions; but he can rely on a considerable growth of traffic due to the development of new industries along the line. He has only to guard against projecting the traffic curve so far ahead that the expenditure made on the strength of that estimate will be so great that the profits on the enterprise will not pay the fixed charges during the first few years after construction and the road be thus thrown into the hands of a receiver.

The revision engineer has an entirely different problem. The road has passed the breakers of financial uncertainty and the traffic has perhaps in most cases, reached such a magnitude that even the utmost improvement in gradients and alignment will not relieve its congestion. Under these conditions it will be possible to arrive at very close estimates of the cost of operation due to excessive grades, rise and fall, distance and curvature, by a careful analysis of the cost of transportation. However it may be that the traffic of the road is such that even if the train loads were increased to their maximum by the revision of grades and alignment, by the use of larger and more efficient locomotives, and by a reduction of the ratio of the dead load to the total load, the cost of operation would be excessive on account of the congestion of traffic. In this case the engineer must determine what amount of traffic would be benefited by an improvement of the alignment and of the grades, and must also determine what additional expenditure will be necessary to provide additional sidings or parallel tracks. If parallel tracks or additional sidings are necessary the conditions of operation will be changed and the estimates of the cost of transportation made under the old conditions will need to be modified.

The writer has prepared a diagram from the statistics published by the Interstate Commerce Commission, which diagram shows the per cent of variation of the amount and cost of railway traffic in the United States for each year since 1890, using the figures for that year as a basis of comparison. This diagram shows that the average train load has increased in very nearly the same proportion as the number of tons hauled per mile of line, indicating that the phenomenal increase of traffic in the last ten years has been taken care of largely by the increase of the train load.

The cost per train mile and also per ton mile decreased between 1890 and 1897, showing that in that period, the increase in train load reduced the expense of operation. From 1897 until 1901 the increase in train load resulted in an increased cost per train and a decreased cost per ton mile; but since 1901 the increase in train loads has materially increased the cost per train mile and also slightly increased the cost per ton mile.

These figures would indicate that up to a certain amount of traffic any increase in the train load will result in the reduction of the cost per ton, but that beyond this point an increase in tonnage without providing for the free movement of the trains, will increase the cost per ton mile. Considering that these figures are the average for the United States, and that many roads have not reached their full capacity for handling traffic while many other roads have spent large sums of money in double tracking and grade revision, we must conclude that there is a point beyond which it is useless to reduce grades and improve the alignment without increasing the facilities for handling trains.

Another phase of revision is that the amount of traffic offered to a well established road will depend to a very considerable extent on the financial condition of the country. The revision engineer should be familiar enough with the business life of the country to be able to judge, in some measure at least, the variations in the amount of traffic to be expected. If the time be one of prosperity with all the evidences of a healthy business situation, the railway may expect a material increase in traffic; if financial unrest prevails, or there is evidence of over speculation, a falling off of the traffic may be expected. This is quite strikingly shown in the diagram by the great decrease in traffic in 1894, closely following the panic of 1893. Some new traffic may be developed in new territory by means of feeder lines, but even the growth of this traffic will be affected very largely by the financial condition of the country. Familiarity with the financial conditions will enable the engineer to judge in any particular case whether it will be more economical to provide the lowest cost of operation for the traffic at the rush periods and pay excessive interest charges in the dull season, or to provide for the lowest cost of operation for the minimum

amount of traffic and pay excessive operation expenses in the rush period.

Thus we have seen that the growth of railway transportation has brought to the revision engineer much broader questions than were given to his predecessors, who have built so well that need has come for much revision. To decry the old locations as mistakes of judgment is as bad as to accuse the shoemaker of being wrong in making shoes to fit children who will soon outgrow them. The growth of traffic has been beyond all precedent and we may expect it to continue to grow for a time at least; nevertheless the work of the locating engineer is gradually and surely changing from that of new location to that of revision. The locating engineer was the standard bearer in the great invasion of the west; the revision engineer will provide the way for greater growth of our commerce and productive industries.

Caisson No. 2 as seen from West Side of River - Nov. 15, 1905

FIELD WORK IN CONNECTION WITH CAISSON SINKING.

B. Van de Greyn, C. E., '09.

This article will take up the field work done in connection with the sinking of the caisson of Pier Two of the Kaw River Bridge, Sixth Street Viaduct, in Kansas City, Mo. Waddell and Hedrick were the consulting engineers, E. E. Howard was resident engineer, and the writer, principal assistant engineer. The substructure work was done by Kahmann & McMurray, contractors.

Methods of triangulation for pier location and descriptions of caissons in general can be found in text books and engineering literature. Therefore, in this article, these subjects will be touched upon only in a general way; but the work subsequent to the triangulation will be treated more fully.

Triangulation. The main base line was laid on the Chicago Great Western railroad bridge shown on the left edge of the illustration. The line was run on the top of the ties parallel to and just outside of the track and extended back to intersect with the bridge tangent. In this line a hole was punched in the top flange of the end floor beam at the fixed end of the first and third span of the bridge. For the sake of convenience call the intersection of base and line and bridge tangent A, the first punch hole B, and the second punch hole C. Distances A B and B C were measured with base line accuracy, and the angle at A determined. The distance A B was found to be 299.532 feet and B C, 406.656 feet.

The Kaw Bridge consisted of two spans, each of about 300 feet length. Pier 1 and Pier 3 were on the east and west shores of the river, and Pier 2 in the middle of the stream. The angles to be turned off from the base line at the points B and C to form an intersection with the bridge tangent at the desired pier centers were calculated. Then with the transit set over B and C in turn, these calculated angles were accurately turned off and permanent foresights put up and firmly secured. Probably the most accurate way in which to establish such a reference line is as follows: suppose transit to be set up at B; sight on C and turn off the angle calculated; mark the line on a board securely fastened with its plane perpendicular to the reference line. Call this point D. With transit still at B read the angle C B D very accurately, in such a way as to eliminate as much as possible all errors. The angle C B D as now determined will be slightly greater or less than the required angle. Move transit to C and read angle B C D; calculate the length of line B D. Knowing the length B D and the error in the angle C B D as previously determined, it is then easy to calculate the amount that the mark on the board should be moved to correct

the error in the angle. A target can then be painted on the board with a distinguishing letter or number which can be seen with the transit at point B. Of course it is not always possible to have a board target, nor is it always best; but the above method can be used whatever kind of monument is used for a permanent foresight. It is convenient to have permanent foresights which can be easily seen from the transit, as much time is saved if it is not necessary to send a man across the river with a flag pole each time a foresight is needed. On the west side of the Kaw River (not seen in the illustration) a second base line was laid off by which a check on the work from the main base line was secured. In general a bridge is not the best place on which to establish a base line due to annoyance from trains passing; but in this case it was the best available and good intersections were secured with the bridge tangent for location of piers.

The Caisson. The caisson was simple in form. It might be described as a big parallelopiped formed by building one box on top of another. The bottom box was open at the bottom, had a roof of solid timber 6 feet thick and sides of box were 3 feet thick; the bottom edge was shod with a steel cutting edge. The inside of this box is what is called the working chamber. This box was kept from being distorted by wooden struts and 1½ inch adjustable rods inside. Two horizontal rows of 12 x 12 inch wooden struts were used, distance between two struts in each row being about 9 ft. 6 in. One row was just below the ceiling of the working chamber and the other row about 1 ft. 10 inches above the cutting edge. Parallel to and close to each strut in the bottom row, 1½ inch adjustable rods extended through the caisson from outside to outside of the caisson walls. The bottom box was made water tight by thorough calking. The top box was open at the top and bottom, the sides consisting of 12" x 12" timbers well drifted together and cross braced with timber struts. Extending up from the working chamber through the 6 foot roof were the supply shafts, mud lifts, air pipes, water pipes, and main shaft through which the work in the working chamber is carried on. The caisson was 22 feet wide, 56 feet long, out to out, built of long leaf southern yellow pine. The outside of both boxes was covered with 2 inch lumber placed with long dimension vertical. The distance from cutting edge to top of 6 foot roof of working chamber was 13½ feet. The construction of the caisson was closely watched in order that the plans and specifications be complied with. The caisson was built on shore to the top of the bottom box, all pipes, etc., being in place, and was afterward launched and floated to position.

False Bottom. It might be well at this point to show the unique method resorted to to make possible the floating of the caisson. It was, as above stated, 22 feet wide and 56 feet long; the dis-

tance from the cutting edge to top of roof of working chamber being 13½ feet; roof 6 feet thick and sides of working chamber 3 feet thick. The writer cannot state just what the weight of the timber was per cubic foot nor the weight of the metal in shafts, etc. The volume of the timber was about 10,000 cubic feet. Assuming the lumber to weigh 40 pounds per cu. ft. then the timber would weigh 400,000 pounds. For shafts, cutting edge, bolts, etc., assume say 20,000 lbs., bringing total weight up to 420,000 lbs. Taking weight of 1 cu. ft. of water as 62½ pounds it is seen that 6,720 cubic feet of water will be displaced, or 3,280 cubic feet of timber will be above the water level.

$$\frac{3280}{22 \times 56} = 2\ 2\text{-}3 \text{ feet.} \quad 13\tfrac{1}{2} \text{ feet} - 2\ 2\text{-}3 \text{ feet} = 10 \text{ feet } 10 \text{ inches,}$$

which would be the depth of the cutting edge below the surface of the water. The river, however, was of less depth than this, especially near the shore. The following method was then resorted to. A false floor was put in the bottom of the working chamber on the bottom side of the lower row of horizontal struts. The bottoms of the struts were 1 ft. 10 inches above the cutting edge. A floor of 2 inch lumber was nailed to the struts; the floor being made with calking grooves and the whole well calked so as to make the working chamber impervious to the water at the bottom.

Now the depth of the cutting edge below surface of water, when caisson was floated, would be about 1 ft. 8 inches plus 6720 ÷ 22 x 56 feet, or about 7 feet. The depth of the river permitted the caisson to be floated to its position under these conditions. After the caisson was in position the false floor was removed and caisson allowed to settle.

While the construction of the caisson on shore was going on, a tramway was built parallel to the bridge tangent from the shore out to the pier site. This tramway was so located that it would not interfere with the subsequent work on the bridge, such as the false work for the superstructure. This tramway was used to carry concrete (all of which was mixed on shore), timber, and other materials out to the caisson after it had been floated to position. The tramway also served to carry the water and air pipes which extended from the machines on shore to the caisson. In the background in the illustration can be seen the long frame building with two stacks rising from it. This building housed the pump and big air compressors from which the water and air were pumped to the working chamber.

As soon as the tramway was carried out far enough a direct measurement was made on it and the transverse center line of pier marked. Then the places to drive the guide piles were located and marked for the contractor. The guide piles were used to keep

the caisson guided in approximately correct position until it had been settled into the river bed some distance. All the pile driving was done from a barge. The illustration shows tramway, guide piles, and caisson ready for launching.

As soon as the guide piles were driven and capped a temporary platform was built on these. This platform served as a plane on which to locate the center of pier from the base lines and bridge tangent. The bridge tangent and the lines turned off from points B and C on the base line should have intersected at a point if the triangulation work had been done correctly. The error was within the limits of accuracy set for this class of work, being inappreciable. Therefore the reference lines were not changed. A fairly good check on the triangulation work was secured by direct measurement along the tramway.

Before the caisson was launched a boat spike was driven at exactly 13 feet above the cutting edge at each of the four corners of the caisson. Each boat spike had its head cut off so as to allow a level rod to rest upon its top edge. The caisson was then launched and floated to position between the guide piles.

After the sinking was well started the routine work of the engineer, in addition to inspecting concrete, etc., consisted of keeping a record of the position of the cutting edge. As the caisson sank, new boat spikes were put in higher up at exact distance above those last driven so that the exact elevation of the cutting edge could always be ascertained. In putting in such new points the measurements were always made accurately and a record of the distance above the cutting edge kept.

To get the data for calculation of position of cutting edge, the proceeding was as follows. On the caisson the center of finished pier was located by intersection of bridge tangent and one of the reference lines. The transit was set over this point and a right angle turned from the bridge tangent. On the outside edges of the caisson were marked the transverse and longitudinal center lines of the pier. The distances from each of these points to the two adjacent corners of the caisson were measured and noted. This showed how far the center of each side of the caisson at the top was off from the center lines of finished pier. Immediately a level was set up on the caisson and a long backsight taken on a bench mark on the shore and careful foresight taken on each of the four boat spikes. The location of the cutting edge could be fully determined from the above data.

The following is an ideal example. Suppose that the top of caisson is out of position, as shown in figure 1, and that the elevations on the spikes at the four corners are as follows:

Corner 4 elev. = 97.00.
Corner 3 elev. = 96.50.

Corner 1 elev. = 96.80.
Corner 2 elev. = 96.30.

Further, suppose the distance from boat spikes to cutting edge to be 30 feet and that the top of caisson is 5 feet above the boat spikes. The caisson is 22 feet wide and 56 feet long. By the relation of similar triangles it is easy to calculate the position of cutting edge shown in figure 4. Figures 2 and 3 explain themselves, being intermediate steps in the calculation. In figure 2 d′ is given as .08 feet. By similar triangles

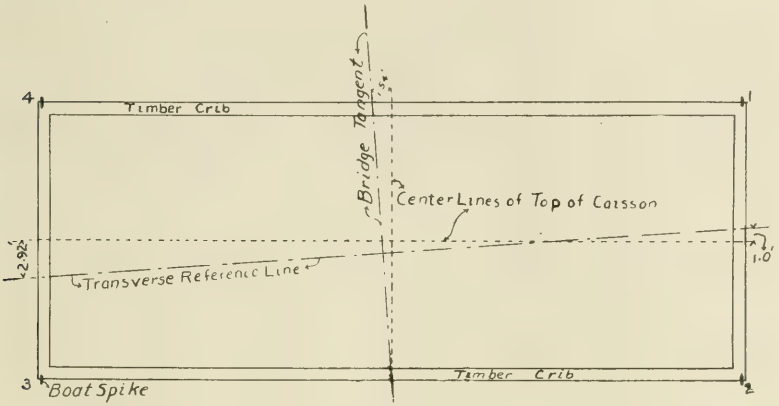


Fig. 1

$$\frac{0.2}{56} = \frac{d'}{35} \text{ — or } d' = .12 \text{ feet;}$$

but d′ must be corrected, as is obvious from figure 4, by the amount $-\frac{1.54}{22} \times .5$ or — .04 feet, as the caisson is tilted two ways. This makes d′ = .08 feet. The same method is used in finding the position of the other three sides. The hypothenuse is used in the relation instead of the leg of the triangle, but this does not introduce any appreciable error.

The results shown in figures 1 and 4 are what the contractor needs. The sketches 1 and 4 and a short letter of instruction—if needed—are given to him. A copy of sketches and letter should be kept by the engineers for several reasons. Generally, instead of giving elevations as shown on figure 4, the amount each of three corners is above the fourth low corner is given in feet and inches.

The instrument work was done immediately after the blowing or settling of the caisson so that there was no movement of

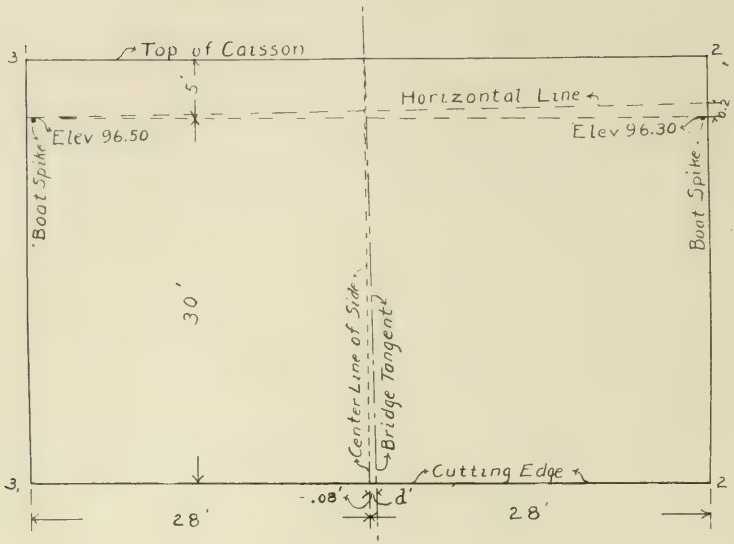

Top of Caisson
Horizontal Line
Elev 96.50
Elev 96.30
Boat Spike
Boat Spike
5'
30'
Center Line of Side
Bridge Tangent
Cutting Edge
.08'
d'
28'
28'
3
2
3
2

Fig. 2

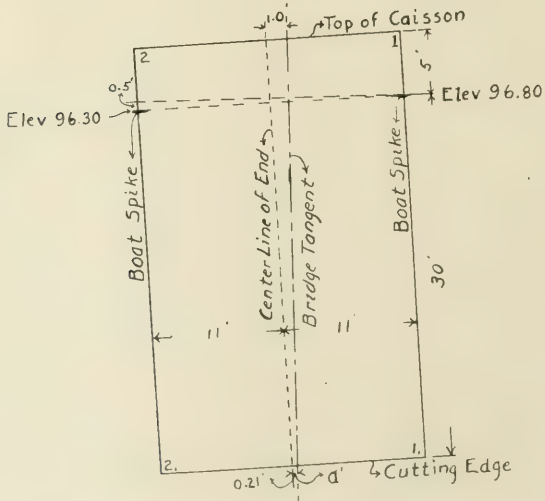

1.0'
Top of Caisson
Elev 96.80
Elev 96.30
0.5'
5'
Boat Spike
Boat Spike
Center Line of End
Bridge Tangent
11'
11'
30'
0.21'
a'
Cutting Edge
2
1
2
1

Fig. 3

the caisson during the time the instrument work was being carried on. As the caisson neared bed rock the position of the cutting edge was found after each settling. Throughout the work the caisson was kept in as correct a position as possible. As the caisson neared bed rock every effort was used to keep it where it should be.

Inspection in Working Chamber. Before bed rock was reached there was very little necessity for the engineer to be in the working chamber. Occasionally he had to go down to help the contractor devise some scheme to shift the caisson when it went so far out of true position as to become alarming. When bed rock—soap stone in this case—was reached, the stone was leveled off somewhat; and a trench 18 inches wide at the bottom, 3 feet wide at the top, and about 18 to 24 inches deep was cut out along the sides of the working chamber just inside the cutting edge. This was done to guard against slipping of the caisson and in case the gravel overlaying the soapstone was scoured out.

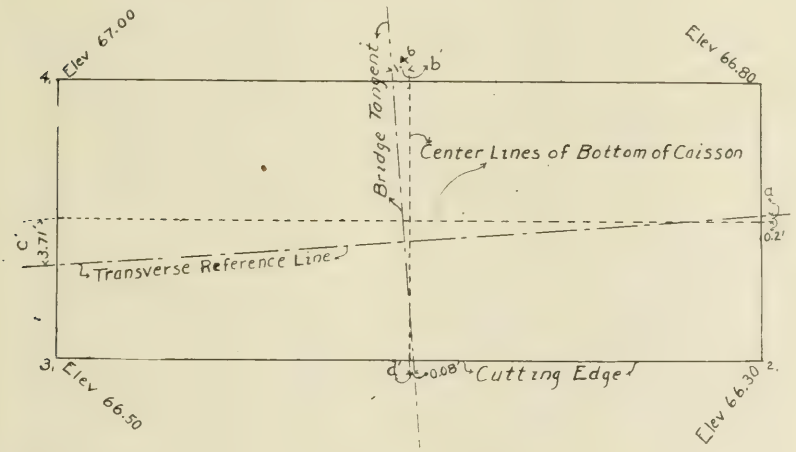


Fig. 4

Filling the Working Chamber. After the foundation had been prepared the work of filling up the working chamber and the several shafts was started. During this work constant inspection was maintained, only those inspectors being used who could stand the air pressure. The inspectors took turns, some inspected the concrete mixing on shore and the others the placing of the concrete in the chamber. The concrete was mixed quite dry and let down through the material shafts into the working chamber. It was deposited at the ends of the working chamber first and well tamped. The chamber was gradually filled, that part nearest the main

shaft being done last necessarily. After the working chamber was completely filled, the shafts were entirely filled with concrete.

In this article the term "caisson" has been used altogether. Properly that part from the cutting edge to the top of the 6 foot roof of the working chamber should be termed "caisson" and the open box above it termed "crib." It has been thought needless to state that the crib is carried up and kept filled with concrete as the caisson and crib settle. The concrete, of course, furnishes the immense weight needed to force the caisson down through the obstacles encountered.

In General. In the case of an octogonal or circular pier the same scheme as herein outlined can be used in locating the cutting edge. In general it may be said that in the case of shallow rivers a tramway is built, as shown in the illustration, and the concrete materials are mixed on shore and carried out on the tramway; while in the case of a deep river the concrete aggregates are mixed on barges anchored near to the caisson and all work handled from the barges.

Often, in order to save timber and concrete, the crib work is stopped and the shaft of the pier commenced on the crib before the cutting edge reaches bed rock. In such a case extreme care should be exercised in giving the center lines for bottom of shaft that these lines will coincide with the correct center lines of the pier when the caisson comes to rest on its foundation. This method should be used only when the cutting edge is but a short distance from bed rock, as the movements of a caisson will not always be just as they are calculated. Also the shaft should be made somewhat larger all around than the plan size so that when bed rock is reached a little shifting of the remainder of the shaft can be done if found necessary. The practice of starting the shaft on the crib when the caisson is any considerable distance above the foundation is a bad one, as the actual direction of movement of the caisson may be quite different from what the engineer supposed it would be. Under such conditions the top of the shaft already built might be so far out of true position, when the caisson reached bed rock, as to prove disastrous. On the Kaw River Bridge the crib work was stopped and the shaft started when the cutting edge was a few feet above bed rock in order to save concrete. The caisson acted just as anticipated and the top of the shaft was very little out of true position. The advice of the superintendent as to the future movement of the caisson and crib will be valuable if he is a man of considerable experience in pneumatic caisson work.

Pressure in Working Chamber. A few words might be said as to variation of the pressure in the working chamber. When blowing a caisson to settle it, the amount the water rises in the chamber depends on the character of the material the cutting edge

is in. For instance, if it is in stiff clay the caisson can be blown and settled two or three feet without any water apparent at all, while if it is in soft material or sand, the water will come up appreciably. Mr. E .E. Howard informed the writer that he had been in caissons where on settling the water came up two feet above the cutting edge. Of course the pressure varies somewhat in the proportion of the hydrostatic pressure; that is, 0.434 H pounds per square inch, where H is the depth in feet below the water surface. However, it will not always hold to this exact amount, in fact it rarely does, depending on the class of material being excavated. In stiff clay the pressure can be run down considerably below the theoretic amount, or run up above this amount without much leakage in either case. To hasten the work of getting out the material the pressure in clay is often run up considerably. In sand or soft material, on the other hand, as soon as the pressure is brought up very much above the hydrostatic pressure, air is bound to be forced out around the cutting edge as is shown by the bubbling of the water at the surface outside.

In general it might be said that in clay the pressure is kept a little below, and in sand or soft material, a little above the true hydrostatic pressure.

The operation of marking lines on the top of the pier coping for position of shoes of the steel span comes under the head of superstructure, rather than substructure work, and will therefore not be considered in this article.

RIBBED CAST IRON BASEPLATES.

C. E. Noerenberg, B. S., '07.

(Research Fellow.)

It is singular in this "age of engineering," when the design of most details of engineering construction has been reduced to the application of a formula or theory, that the design of such an important detail of modern mill and steel office building construction as the baseplate, has been neglected. As far as the writer has been able to learn, but few investigators have attempted to study the baseplate analytically, no theoretical formulas have been evolved as yet and no actual tests or experiments whatever have been made. Its design is left to mere guess work or the application of empirical formulas such as F. E. Kidder's or W. F. Scott's.

Aside from the formulas deduced for plain baseplates without ribs by Dr. N. C. Ricker, Professor of Architecture at the University of Illinois, as published in The Technograph No. 20, pp. 109-114, only two pages of a theoretical nature were discovered in all the English, French, and German literature available to the writer and these were written by Prof. E. Claussen in his text, Statik und Festigkeitslehre, pp. 180-184. His theory with some modifications was used as a basis for an investigation performed under the direction and suggestion of Dr. Ricker and presented in June, 1907, by the writer to the University of Illinois as a thesis in Architectural Engineering, of which a brief report will be made.

Since concrete, stone or brick masonry has a far smaller strength under compression than has iron or steel, a larger area of the former than of the latter will be required safely to transmit the load supported on a cast iron or steel column to its masonry foundation. The purpose of the baseplate is uniformly to distribute the weight of the column and its load over a sufficiently large area to keep the unit pressure on this area from exceeding that allowed in safe engineering practice. The size and dimensions of the baseplate are accordingly governed by the permissable stresses in masonry and cast iron.

The entire area of the baseplate transmits uniform pressure to the foundation, or, it may be considered as affected by a uniform load due to the upward pressure of the foundation and as supported by a small area at its center against this upward reaction. Therefore the outer edges of the plate are unsupported and the load per unit area creates a bending moment that tends to break the baseplate. This bending moment can be resisted in only two ways, by increasing the thickness of the plate from the outer edges toward the center as in the plain baseplates, or by the insertion of a number

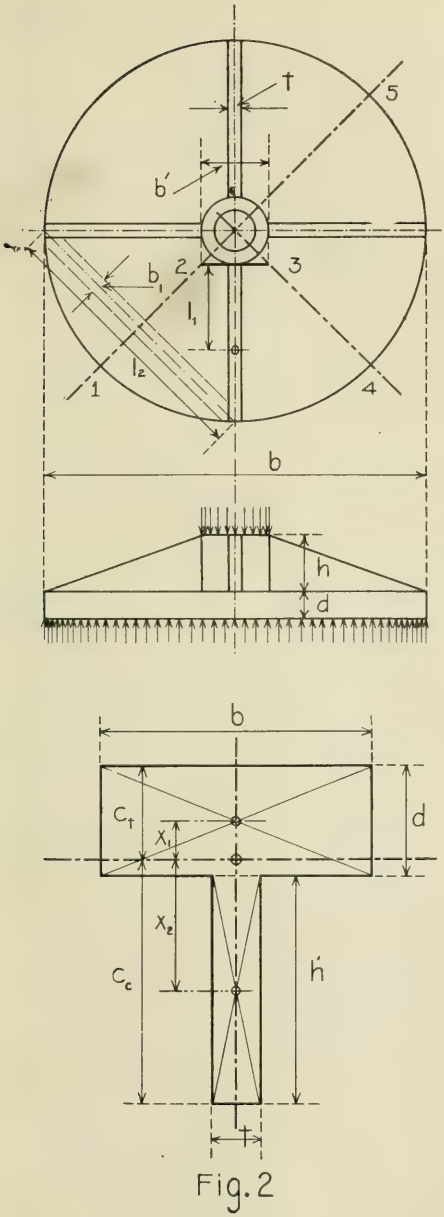


Fig. 2

of bracket-like ribs which support and stiffen the outer edges of the plate and act as cantilever beams to transfer the load of the area supported to the center column support or hub. The plate between the ribs supports and transfers the load to the ribs and acts as a uniformly loaded beam fixed at both ends to the center lines of the rib.

Prof. Claussen states that each rib supports independently its proportionate portion of the pressure area of the baseplate like an inverted bracket and the bending moment due to its load is opposed by the resisting moment of the T-shaped cross-section of the rib and a portion of the plate tangent to the hub at the root of the rib thus assuming that the plate breaks along straight lines equi-distant from two adjacent ribs, first from the edge of the baseplate toward the hub and then directly across at right angles to the rib in a plane tangent to the hub, leaving the hub uninjured. According to these assumptions, theoretical formulas were evolved, baseplates of nine different types were designed, and as a proof of the correctness of the formulas were tested to destruction.

NOTATION.

Let P = total load on baseplate or total reaction of masonry in pounds.

p_1 = max. permissible unit pressure of column on baseplate in pounds per sq. in.

p_2 = max. permissible unit pressure of baseplate on masonry in pounds per sq. in.

Let A_1 = total area necessary to support column in sq. in.

A_2 = total area of baseplate in sq. in.

t = thickness of metal ribs and hub in inches.

d = thickness of plate in inches.

h = height of rib above plate in plane tangent to central hub in inches.

a = area of portion of plate supported by rib or lying outside the fracture line in sq. in.

l_1 = lever arm of this pressure area or distance from fracture line to center of gravity of area in in.

l_2 = greatest distance between center lines of adjacent ribs in inches.

b_1 = thickness or width of strip considered as a beam in inches.

S = maximum permissible fiber stress in pounds per sq. in.

M = bending moment acting at right angles to fracture line in inch pounds.

I = moment of inertia of fracture section.

c = distance from neutral axis of fracture section to most distant fiber in tension in inches.

In order completely to detail a baseplate it is necessary to have the following dimensions:

1. The size of the top area on which the column rests.
2. The size of the bottom area which rests on the masonry.
3. The thickness of the bottom plate.
4. The height of the rib at the center next the hub.

The shape of the baseplate, the number of ribs and the thickness of metal in the ribs and hub are chiefly a matter of judgment though of course they influence the design after being assumed.

In order to keep within the allowable limits, the two first areas are at once determined by the load and the allowable unit pressures.

$$\text{or } A_1 = \frac{P}{p_1} \quad \text{and } A_2 = \frac{P}{p_2}$$

Then, as the plate acts as a beam, its thickness or depth will also be determined by its load. It may be considered as divided into strips parallel to the line joining the ends of the center lines of adjacent ribs, whose breadth is B_1, whose thickness is D, and whose length is l_2.

$$\text{For a fixed beam } M = \frac{p\,l^2}{12}$$

$$\text{and for a rectangular section } \frac{I}{c} = \frac{b\,d^2}{6}$$

$$\text{Therefore, since } \frac{M}{S} = \frac{I}{c}$$

$$\frac{P_2\,l_2^2}{12} = \frac{S\,b_1\,d^2}{6}$$

But B_1 = unity since S is measured in terms of unity.

$$\text{Therefore, } d = l_2 \sqrt{\frac{p_2}{2\,S}} \text{ where } l_2 \text{ is determined from } A_2.$$

It only remains to determine the height of the rib. According to Prof. Claussen's theory, the assumed fracture line is represented by the line 1-2-3-4 in Fig. 1. It is also assumed that the resistance of the plate to fracture along the radial lines 1-2 and 3-4, is negligible, since that part of the plate is already under a bending moment. But as the length l_2 decreases from the outer edge of the basplate toward the center, the thickness D should also decrease. But since this thickness is always made the same from edge to hub in practice, there evidently is an excess of strength not taken into consideration and whose amount cannot be easily determined. As will be shown later, this is probably a fault in the theory. However, for want of better information, it was assumed that the bending moment of the rib was opposed by the resisting moment of only that part of the cross-section which was perpendicular to the line of action of the moment, the T-shaped cross-section 2-3.

Since each rib supports its proportionate portion of the area, the bending moment is evidently a $p_2\,l_1$ and must equal the resisting moment of the cross-section.

$$\text{Therefore, } \frac{I}{c} = \frac{a\,p_2\,l_1}{S}$$

where $\frac{I}{c}$ equals the section modulus of the T-shaped cross-section of Fig. 2.

The moment of inertia of this section is

$$I = \frac{t\,c_c^3 + b\,c_t^3 - (b - t)\,(c_t - d)^3}{3}$$

$$C_t = \frac{(h + d)^2\,t + (b - t)\,d^2}{2\,A}$$

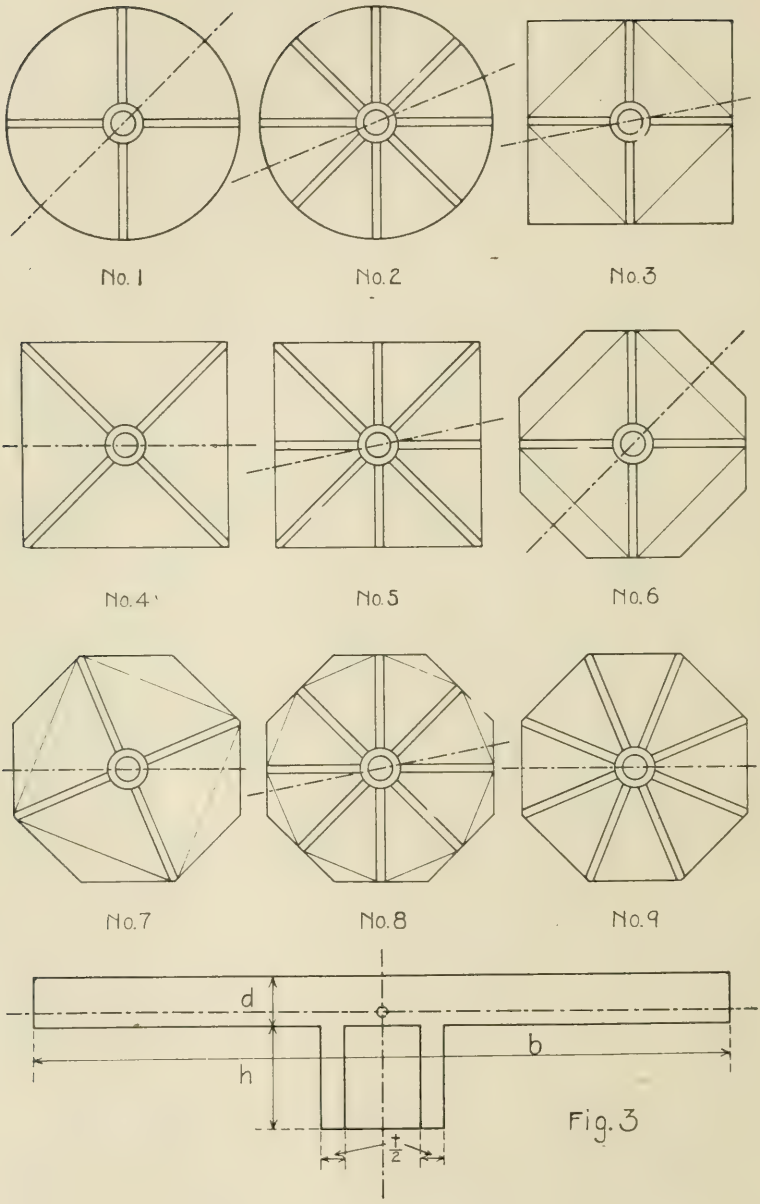


Fig. 3

$$C_c = (h + d) - c_t$$
$$A = b\,d + h\,t$$

After substituting and reducing

$$\frac{a\,p\,l}{S} = \frac{I}{C_t} = \frac{1}{6}\,\frac{b^2 d^4 + 4\,b\,d^3\,h\,t + 6\,b\,d^2\,h^2\,t + 4bd^3ht + h^4t^2}{b\,d^2 + 2\,d\,h\,t + h^2\,t}$$

Since this equation is unsolvable for h, the unknown quantity, it is necessary to use the "cut and try" method in obtaining it; i. e., by assuming a certain section by giving h some actual value and obtaining a numerical result for the $\frac{I}{C}$ of this particular section. If this result is very nearly equal to the required $\frac{I}{C}$ or $\frac{a\,p\,l}{S}$ the section will be suitable and h will have this value. If not, other sections must be chosen until the actual result for $\frac{I}{C}$ does equal the required one.

By the use of these formulas nine different types of baseplates were designed, square, circular, and octagonal, with four and eight ribs of different arrangement as shown in Fig. 3.

The bottom area of all the baseplates was made 400 sq. in. in size for purposes of comparison and the allowable pressure per sq. in. was fixed at 50 lbs., in order that the strength of the baseplates would not exceed the capacity of the 600,000 lbs. Riehle testing machine in the Laboratory of Applied Mechanics on which the tests were made. Therefore, the safe load for which the baseplates were designed was 20,000 lbs. and with a factor of safety of 10, the ultimate strength was 200,000 lbs. The central hub or column bearing area was made circular in all the types, the outside diameter being 4 inches and the thickness of metal in hub and ribs ¾ inches. The formulas were also arranged to satisfy the building ordinances of the city of Chicago. Therefore, the following unit stresses were adopted as safe.

Maximum fiber stress in cast iron tension, 2,500 lbs. per sq. in.

Maximum fiber strength in cast iron compression, 10,000 lbs. per sq. in.

Maximum pressure on concrete masonry, 12½ tons per sq. ft., dimension stone or brickwork in Portland cement.

The tension stress governed the design of the section, as in no case was the ratio of C_t to C_c greater than or equal to 1 to 4, the ratio of 2,500 to 10,000. The portions of the plates lying outside the lines joining the extreme ends of the center lines of adjacent ribs act as simple baseplates and were tapered from the required

distance along these lines to ⅜ of an inch at the edges or corners. The dimensions of these baseplates are included in Table I.

These specimens of each of the nine types were cast, the cast iron being of fair average commercial quality. One-fifth of the baseplates exhibited flaws along the fracture section. The metal was fairly brittle in nature and most probably the tensile strength was low. It is regretted that no small test specimens were made and hence no values of the exact tensile and compressive unit strength of the metal determined.

The most difficult point in making the tests was the selection of a suitable and proper cushion, and considerable experimenting was done before final acceptance. It was impossible to place the baseplate directly upon the bed of the machine, because this would not reproduce the conditions occuring in actual practice. It was necessary that a cushion or bed be placed under the baseplate, which should be as perfectly elastic as possible and which should still be of sufficient rigidity to cause the pressure to be resisted over the entire surface as nearly uniformly as possible. To make the theory and tests agree, the pressure per unit area had to be kept uniform over the entire area until the baseplate failed by fracture. It was found that a bed composed of ten or twelve layers laid in alternate directions of ⅞ inch by 3 inch pieces of oak wood 26 inches long planed on all sides, possessed the necessary requirements. Each layer was composed of eight pieces laid side by side and separated by ¼ inch spaces to allow for expansion while under pressure. The bed was then 26 inches square and 10 inches high and showed a compressive strength of over 1,500 pounds per sq. in.

Each value in the column in actual ultimate strengths or breaking loads, and in the column of weights in Table I is the average of the three specimens of each kind.

It is evident from an inspection of the column in Table I containing the factors of safety of the fracture section 2-3, that there is a great discrepancy to be accounted for before the formulas and theory can be proved correct. The values of these factors of safety, varying from 28 to 16, with an average of 21, are much higher than the assumed one of 10, and the usual one of 6 to 8 to 10 for cast iron imply that the baseplates as designed are too strong. From a study of the fractures of all the baseplates as they actually did break, it was found that in no case did the baseplate break along the assumed fracture line. But the tendency seemed to be to break in straight lines through the center of the baseplate parallel to the center lines of the ribs or along a diameter. Because of the unaccounted for excess strength of the assumed fracture section along the radial lines, the ribs did not break out independently of each other according to Prof. Claussen's theory, but were tied together by the plate.

SHEET C.

Area = 400 sq. ins.

TABLE I.

Thickness of metal in hub and ribs = ¾".

Hub is 4" in diam.

FIRST SET OF TESTED PLATES.

No. of Plate	No. of Ribs	Least Side or Diam.	Thickness d	Height of Rib h	Total Height d+h	Weight in Pounds	Actual Ultimate Strength	Fracture Line 2-3				Fracture Line 1-5			
								Act. $\frac{I}{C}$	Reg. $\frac{I}{C}$	Theoretical Safe Load	Factor of Safety	Act. $\frac{I}{C}$	Reg. $\frac{I}{C}$	Theoretical Safe Load	Factor of Safety
		"	"	"	"	#	#			#				#	
9	8	22.00	0.937	4.375	5.312	152	566 000	5.52	5.40	20 000	28.30	44.36	19.26	46 065	12.29
5	8	20.00	1.000	5.000	6.000	164	542 000	7.03	7.14	20 000	27.10	52.97	19.87	53 320	10.16
2	8	22.625	0.875	4.375	5.250	143	456 000	5.41	5.32	20 000	22.80	43.62	19.20	45 430	10.04
8	8	22.000	0.875	4.375	5.250	139	452 500	5.41	5.40	20 000	22.62	43.47	18.81	46 230	9.79
6	4	22.000	1.562	3.375	4.937	169	408 600	9.81	9.64	20 000	20.43	37.08	19.26	38 505	10.61
4	4	20.000	2.000	3.125	5.125	240	373 300	10.69	10.27	20 000	18.67	37.01	20.00	37 015	10.08
7	4	22.000	1.687	3.250	4.937	181	353 300	9.77	9.64	20 000	17.66	36.74	19.26	38 150	9.26
1	4	22.625	1.625	3.375	5.000	171	348 400	10.06	9.60	20 000	17.42	38.53	19.20	40 135	8.68
3	4	20.000	1.437	3.375	4.812	148	329 600	9.33	9.41	20 000	16.48	34.33	19.87	34 555	9.54
														47 760	10.55
Av.	8					150	504 000			20 000	25.20			37 670	9.63
Av.	4					182	362 200			20 000	18.13				
Grand Av.						168	425 500			20 000	21.27			42 155	**10.05**

which in turn was stiffened by the ribs. Evidently the assumed theory is correct.

The baseplate tended to and actually did fracture along a line so placed that the element of the stiffness was not included. As suggested by Dr. Ricker, this line is a diameter of the baseplate as line 1-5 in Fig. 1. If we assume this fracture line is correct, compute the actual value of the section modulus of this new fracture section and, by proportion from the required value of $\frac{I}{c}$ or $\frac{apl}{S}$, compute the actual strength of each baseplate with respect to this new assumption, we shall obtain data sufficient to prove this statement. From an inspection of the factors of safety for the fracture line 1-5 in Table I, which vary from 12.29 to 8.68, it is at once evident that the actual strengths of the baseplates are as nearly uniform as this material, cast iron, will permit, and that the average value of the factor of safety, 10.05, is almost exactly equal to the assumed one. This in itself is sufficient to prove the correctness of the assumption of the second fracture line, the diameter of the baseplate.

As the entire baseplate acts as a beam with overhanging ends, loaded over the entire area, supported at its center and therefore under a bending moment, its ultimate strength should be determined by the value of the modulus of rupture instead of the value of the ultimate tensile strength of the metal, since cast iron is a material whose value of M, the ratio between its ultimate compressive strength and its ultimate tensile strength, is not equal to 1, but on the contrary is equal to 4 for ordinary iron. Without entering a lengthy discussion here, it is stated by such eminent authorities as Bach, Keep, Burr, Johnson, and others, that the strength of such materials with no definite elastic limits and without the limits of Hooke's law, should be computed by the safe tensile strength of the material for the safe working load and by the modulus of rupture for the ultimate load. Since the ultimate strength of the baseplate is the one that was determined in these tests, it seems but just to use the modulus of rupture as the determining factor. According to Prof. J. B. Johnson, as stated in "Theory and Practice of Modern Framed Structures," the value for the modulus of rupture is 1.81 times the tensile strength when M equals 4, a fair ratio for cast iron. Then the reduced factor of safety for these baseplates is 5.55 which is a fair value for commercial cast iron. This affords another proof of the correctness of the theory and the new assumption.

The first series of tests was considered interesting and valuable enough to be supplemented by a second series on baseplates designed according to the corrected theory. So another set of

baseplates of the nine different types was designed, cast, and tested to destruction in a manner similar to the first set but with greater care paid to the small details.

The correct formulas are now

$$A_2 = \frac{P}{p_1},\ A_1 = \frac{P}{p_2} \text{ and } d = l_2 \sqrt{\frac{p_2}{2s}} \text{ as before}$$

$$\text{and } \frac{I}{c} = \frac{a\, p_2\, l_1}{s} \text{ for the correct value of h}$$

where $a = \frac{1}{2} A_2$ and

$\frac{I}{c}$ = section modulus of the LEAST fracture section through the CENTER of each baseplate, such as the T-shaped cross-section of Fig. 3. It was again necessary to obtain the values of H by the "cut and try" method.

The second series of baseplates were accordingly different from the first series in only the dimension H, as this was the only unknown quantity affected by the change to the new cross-section. A_1, A_2 and d are unchanged. The weights and ultimate strengths in Table II are again averages of three baseplates of each type.

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The second set of tests were made on a similar bed and under similar conditions to the first set and the quite remarkable uniformity of the values of the actual ultimate strengths of the nine different types of baseplates seem to prove undoubtedly the correctness of the theory of design and the method of testing. The largest variations both high and low from the mean, are the strengths of the square baseplates both four and eight-ribbed, and it seems that from the shape of these baseplates, the great varia-

Area = 400 sq. ins. TABLE II. Safe Load = 20,000 lbs.

t = 1½ ins. SECOND SET OF TESTED PLATES. b′ = 4 ins.

No. of Plate	No. of Ribs	Thickness d	Height of Rib h	Total Height d + h	Weight in pounds	Actual Ultimate Strength	Factor of Safety
8	8	0.875	2.687	3.562	117	337 800	16.89
2	8	0.875	2.687	3.562	120	326 300	16.32
9	8	0.937	2.687	3.625	117	311 400	15.57
5	8	1.000	2.750	3.750	133	**276 300**	**13.82**
4	4	2.000	1.750	3.750	220	**370 100**	**18.50**
1	4	1.625	2.000	3.625	173	316 400	15.82
6	4	1.562	2.125	3.687	152	308 200	15.41
7	4	1.687	2.000	3.687	145	303 800	15.19
3	4	1.437	2.375	3.812	145	**239 700**	**11.98**
Average	8	0.922	2.703	3.625	122	312 950	15.65
Average	4	1.662	2.050	3.711	167	307 640	15.38
Grand Average..		1.333	2.340	3.673	147	310 000	**15.50**

tion in distance from the outer edge to the center and accordingly the variation in the bending moment at different points on the hub, that these baseplates would naturally be the most inconsistent of the set. The strengths of the remaining six baseplates are remarkably uniform for cast iron, not varying more than five per cent from the mean. Also the average strength of the eight-ribbed baseplates is almost exactly equal to the average of the four-ribbed baseplates. This uniformity, both in this set and in the first set, is surely a proof of the correctness and reasonableness of the theory.

The cast iron of which the second set was made, was of much better quality than that used in the first set and of a far more uniform texture. It was tougher and more ductile and did not present one flaw in breaking. Test specimens for the determination of the tensile, compressive, and flexual strengths of the metal in the baseplates, were made at the same time the baseplates were cast, two specimens of each kind of test piece being cast, at the beginning of the pour and two at the end. These test pieces were excellent specimens of a very good quality of cast iron, the fractures being light gray, lustrous, slightly granular toward the center, and without a flaw. They were the standard forms adopted by the American Society for Testing Materials and gave the following unit average strengths:

Ultimate strength in pure tension, Average of 4, 24,700 lbs. per sq. in.

Ultimate strength in pure compression, Average of 4, 105,100 lbs. per sq. in.

Modulus of rupture in flexure, Average of 8, 45,600 lbs per sq. in.

By means of these unit ultimate strengths it is possible to determine exactly the factors of safety of the baseplates. As the ultimate strength in tension was 24,700 lbs. per sq. in., the safe stress, 2,470 lbs., assuming a factor of safety of 10 which is large, is very nearly equal to the one that was adopted, 2,500 lbs., as prescribed by the Chicago building ordinances. The value of M; the ratio between the ultimate tensile and compressive strengths, 4.26, is close to the generally assumed value of 4. The ratio between the ultimate tensile strength and the modulus of rupture, 1.85, is almost exactly equal to the ratio obtained from Prof. Johnson's formula when m equals 4.26. Then by the use of the modulus of rupture as the determining factor in place of the ultimate tensile strength as previously explained, the factor of safety of the baseplates, 15.50, is reduced to 8.38, a value which is very reasonable for the excellent quality of cast iron in the baseplates. Or in other words, assuming that since the baseplate is under a bending moment, the modulus of rupture of cast iron should be the unit determining factor in place of the ultimate strength in pure tension, the baseplates of the first set broke at 5.55 times the safe working load that they were designed for according to the proposed theory, and the baseplates of the second set broke at 8.38 times the safe working load. The difference in these factors of safety is due to the difference in quality of the cast iron. The values of these factors of safety lie within the safe limits of general engineering practice and therefore the theory and method of design is established and its correctness proved.

Since all the baseplates of the second set possessed the same strength and area, it is evident that a comparison can easily be made between the nine different types so as to determine which type most closely conforms to "the second fundamental principle of engineering design," that of economy. By inspection of Table II, it is seen that the eight-ribbed baseplate is far more economical in the use of material than is the four-ribbed one, since its average weight is 122 lbs. as compared with 167 lbs. Because of the greater variability of the square type of baseplate, both in weight and strength as compared with the circular or octagonal form, it seems to be the most objectionable and inconsistent. Between the remaining three eight-ribbed baseplates there is little choice. But it is believed that as the square approaches the octagon and then the circle as a limit, that the circular is the most consistent and its rank among both the eight and four-ribbed baseplates makes it the most representative. The ribbed baseplate can also be compared very favorably with the plain base-

plate both as to stability and economy of material.

By an inspection of the column in Table II containing the values of "d+h," it is seen that the total height of the baseplate is nearly uniform for all of the nine types for the same load. This seems to be consistent. The variation in weight between the various types is then due to the position of the metal, that in the lighter baseplates being placed in the more advantageous position, the ribs, and in the heavier ones in the plate.

For the purpose of making a comparison of baseplates designed according to these theoretical formulas, with those as usually designed by "rules of thumb," a series of baseplates varying in area from 100 sq. ins. to 1,600 sq. ins. were designed for the maximum pressure per sq. in. on the foundation allowed by the Chicago building ordinances, 173.6 lbs. per sq. in. or 12½ tons per sq. ft. The type chosen was the circular eight ribbed baseplate. The dimension T was made equal to D, as in every case the thickness of the metal in the hub, whose diameter is made equal to the diameter of the column supported, is greater than the thickness of the metal in the column if the column is of cast iron, and is more than sufficient to carry the load on the column whether the column is of cast iron or steel.

With these assumptions there remains to be determined only the special values of P, b, d, and h. The diameter of the baseplate B can be at once determined for each baseplate from its area and P, the safe working load that each baseplate can carry, is equal to the area times the maximum permissible pressure per sq. in. $= 173.6\ A_2$. By substitution in the general formula for d, $d = 0.1863\ l_2$ where l is measured from each plate.

But $l = b \times \cos 67\frac{1}{2}^{c} = 0.3827b$.

Therefore $d = 0.0713\ b$, for this pressure per sq. in.

The value of H must be again obtained by the "cut and try" method where the required $\frac{I}{c}$ must equal $\frac{apl}{s} = \frac{al}{14.4}$

where $a = \frac{1}{2}\ A$ and $l = 0.212\ b$ for a circular baseplate.

$$\text{or } Reg\ \frac{I}{c} = 0.00578\ b^3$$

It is hoped that further investigation will develop a shorter theoretical formula for H which will obviate the necessity of obtaining this value by the "cut and try" method. But $4h = b - 2d + 14''$ is a reasonable empirical formula that will give accurate values of H within two-tenths of one per cent. for this range of sizes.

An inspection of the columns of Table III, containing the dimensions of these commercial specimens, affords some inter-

P = 12½ tons—sq. ft. TABLE III. t = d

CIRCULAR 8-RIBBED BASEPLATE.

Area of Plate in sq. ins.	Safe Load in pounds	Diameter of Plate, b ins.	Thickness of Plate, d ins.	Height of Rib, h ins.	Total Height d + h ins.
100	17 360	11.250	0.812	2.500	3.312
200	34 720	16.000	1.125	3.500	4.625
300	52 080	19.625	1.375	4.250	5.625
400	69 440	22.625	1.625	4.875	6.500
500	86 800	25.250	1.875	5.500	7.375
600	104 170	27.625	2.000	6.000	8.000
700	121 530	29.875	2.125	6.500	8.625
800	138 890	32.000	2.250	7.000	9.250
900	156 250	33.875	2.375	7.374	9.750
1000	173 610	35.750	2.500	7.875	10.375
1100	190 970	37.500	2.625	8.250	10.875
1200	208 330	39.125	2.750	8.500	11.250
1300	225 690	40.875	2.875	8.875	11.750
1400	243 050	42.250	3.000	9.125	12.125
1500	260 410	43.750	3.125	9.500	12.625
1600	277 780	45.125	3.250	9.750	13.000

esting conclusions. The baseplates vary in size from 100 to 1,600 sq. ins. in area and their diameter from 11¼ to 45 inches in length, thus including within this range most of the sizes commonly found in practice. Their safe loads vary from 17,400 to 278,000 pounds or 8.7 to 139.0 tons. The maximum thickness of metal is 3¼ inches and the total height of each baseplate, d+h, always equals $\frac{2}{7}$ of its diameter. It must be remembered that the above short formulas and designs apply to only the circular eight ribbed baseplates when p equals 12½ tons per sq. ft. or 173.6 pounds per sq. in.

Further investigations are being made and will be published later in the form of a bulletin of the Engineering Experiment Station of the University of Illinois.

DESIGN FOR A REINFORCED CONCRETE DOME.

J. T. Vawter, B. S. '04.

A hasty review of the cycles of Architectural history directed toward the recurrance of materials, methods of construction, and forms would be an interesting preface to a consideration of concrete domes, but the space allotted this article prohibits more than the mere suggestion that the historical helix is of small pitch and after a turn of nineteen centuries we find ourselves hardly above the Romans in attempting the problems which they solved in very much the same form and material.

Parallel with the development of reinforced concrete construction, although as yet almost independent, the dome form as a covering for large open floor spaces, as well as a noble element of composition is again growing in favor. The popular form, which is that of a flat spherical segment, is not the result of the adaptability of any particular material, since the last decade has seen it constructed of every material from marble to sheet iron, and even paper; nevertheless the form is one which lends itself admirably to concrete construction.

TABLE I.

UNITS STRESSES IN SHELL.

POINT	1	2	3	4	5	5	7	8	9	10	11	12
Comp. lbs. per □ in.	155	54	38	31	26	25	25	25	25	26	26	27
Shear lbs per □ in.	4	5	6	7	8	10	10	10	10	10	9	8

Comparatively little has been written on the distribution and magnitude of stresses in masonry domes, and nothing of a scientific nature on those domes whose shells are too thin to contain the line of pressure as determined by the gravity method. Mr. Guastavino seems to be the only man, in this country at least, who has given the subject serious consideration. He has given us a very interesting little book on the subject, but unfortunately he has confined himself to a particular material, namely, flat tile laid in cement or plaster, which he has found by experience develops sufficient tensile and shearing strength to withstand the bulging and flexural stresses. As to the magnitude and distribution of those stresses, however, he gives us no information and contents himself with what he seems to regard as the limiting element of his design, the gradually increasing compression

from crown to base. Whether or not this assumption is correct is far from the province of this article to decide, although evidence might be offered on both sides.

If we consider a section of a hemispherical dome shell, comprehended between two meridian planes, making a small angle with each other, and resolve the forces due to its dead weight at successive points into two systems, one tangential and constantly changing direction, and the other horizontal, we feel convinced of the existence of a system of bulging stresses (Fig. 2) which depend for their resistance, either directly, or indirectly by flexure, upon the tensile strength of the material. On the other hand if we consider any particular point on as many separate, symmetrically loaded arches of varying span and radii as could be cut by planes of great and small circles of the sphere passing through it, and consider that the haunches of one may become the crown of another, our imagination is taxed to a point of uncertainty regarding the bulging stresses particularly in the upper zones, and we might be led to believe that they neutralize each other to a far greater extent than is indicated by our stress diagram.

TABLE II.

DISTRIBUTION OF WIND LOADS. PRESSURE 40 LBS. PER SQ. FT.

POINT	1	2	3	4	5	6	7	8	9	10	11	12
Angle	6°	12°	18°	25°	32°	38°	45°	51°	57°	63°	70°	76°
Normal lbs.	6.9	15.	22.	28.	33.	35.	37.	38.	39.	39.7	39.9	40.
Area □ ft.	1.45	4.49	7.43	10.27	13.14	15.91	18.33	20.58	22.55	24.11	25.46	26.50
Load	9.6	66.	162.	285.	429.	560.	666.	760.	856.	936.	975.	1040.

Whether or not Mr. Guastavino has solved the problem of the stresses in thin shelled domes is of far less importance than the fact that he has left us living examples of domes of large span with extremely thin shells whose lines of pressure if drawn by the gravity method would fall far outside the dome itself to say nothing of the prescribed middle third. And still they stand as eloquent examples of economy in material and weight without the assistance of metal reinforcement.

These structures, together with three or four reinforced concrete domes in this country, are also eloquent in calling our attention to the condition that in engineering work of small cost

intuition and rules of thumb as well as ignorance and foolhardiness in varying degrees are always in advance of scientific knowledge. That is, problems like the one presented here usually fall first to men of small education and experience, and science afterward approves or condemns. These facts are mentioned here only to call attention to what is believed by the writer to be a broad open field for investigations.

TABLE III.

HORIZONTAL REINFORCEMENT.

Area No.	Max. Horizontal Stress, Wind and Dead	Areas Sq. in.	Diam. inches = d.	$\frac{P}{A}$	Stress in ring 1 inch high.	Stress in zone 41 inches wide.	Area of Steel, Wind and Dead.	HORIZONTAL RING REINFORCEMENT	
								¾ inch from Extrados	¾ inch from Intrados
1	—							2@¼"□Twstd Bars	4@⅜□"Twstd Bars
2	—							3@⅜"□Twstd Bars	do
3	—							2@¼"□Twstd Bars	do
4	—							do	do
5	—							do	do
6	—							do	do
7	+ 60	2639	492	.023	6.	246	.020	3@⅜"□Twstd Bars	do
8	+380	2963	552	.13	36.	1479	.112	do	3@¼"□Twstd Bars
9	+600	3247	602	.19	58.	2378	.176	4@½"□Twstd Bars	do
10	+1020	3471	658	30	99.	4059	.292	do	do
11	+1400	3666	684	.40	137	5617	.40	do	do
12	+1700	3816	712	.45	160.	6560	.48	do	do
Bottom	2600	93	724	3.6	1303	—	.40	2@½"□Twstd Bars	2@½"□Twstd Bars

The designer in this case is fully aware that he has not analyzed the stresses of the dome as they are actually distributed, but it is believed that the design is safe, practical, and comparatively economical.

The problem of which this design is the result, was to cover with a dome the intersection of a church located in Fresno, Cal-

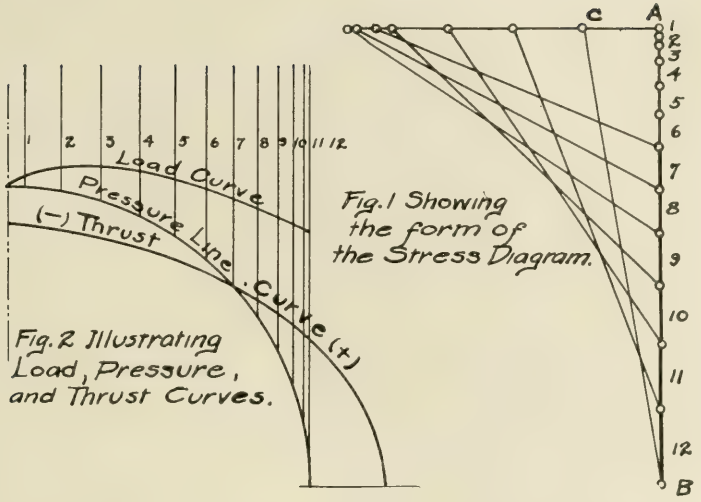


Fig. 1 Showing the form of the Stress Diagram.

Fig. 2 Illustrating Load, Pressure, and Thrust Curves.

Fig. 3 Vertical Projection of Vertical Reinforcement.

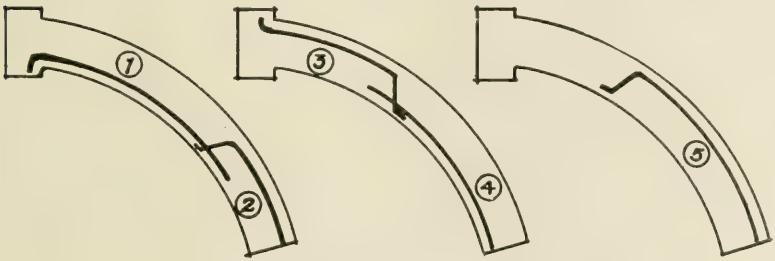
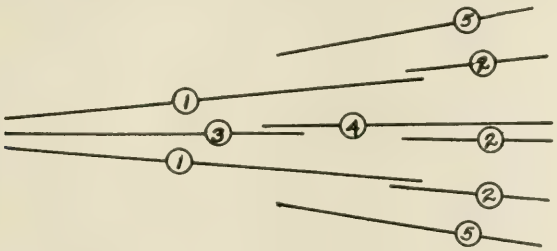


Fig. 4 Horizontal Projection of Vertical Reinforcement.



ifornia. The church was of reinforced concrete throughout and it was desired to make the dome of the same material. The plan of the intersection was an octagon, sixty feet in diameter, the length of the radius of the dome was about 31 feet, the center having been dropped about nine feet below the springing. Precaution was taken against damage due to thermal stresses and sesmic vibrations both of which were claiming considerable attention in that locality at the time. The last two considerations gave rise to the idea of disconnecting the dome shell from the supporting structure entirely, as will be noted in detail later.

A minimum thickness of 4″ was advised by a practical concrete worker as being the thinest section to be trusted even in 1:2:3 concrete, owing to difficulties of construction and irregularities of materials. The maximum thickness of 6″ was an intuitive element of the design, and how well the assumed section fitted the span may be decided by a consideration of the table of unit stresses—Table I.

The increased thickness of the base seems unwarranted by these figures, except probably to develop the increased amount of reinforcement in the lower part, and the thickness of 4″ for the crown seems unnecessarily heavy. In this case however it seemed wise to consider the advice of the experienced builder. A tentative stress diagram was therefore made on the basis of the above dimensions, and after some deliberation the tentative diagram became the final.

The first point taken up in the solution of the problem was the determination of the loads. Since snow is unknown in this locality, and the wind stresses were treated separately, the dead weight of the structure itself was the only consideration.

A section of the dome cut by two meridian planes, making an angle of 15 degrees with each other, was developed graphically and divided into twelve parts of equal length, but with constantly diminishing area and volume from base to crown. The weights of these twelve parts were calculated and laid off to scale on the load line of the stress diagram (Fig. 1). The reaction AB is assumed vertical. The weight of the dome which it is to resist is assumed to be tangent to the dome at point 12. These two forces, AB and BC, are evidently not in equilibrium, but require a horizontal force CA to complete the polygon. This horizontal force is the total outward thrust on the entire area of section 12. The mean unit pressure is $P = \frac{F}{A}$. If we wish to resist this thrust entirely by horizontal rings of reinforcement, we may find the magnitude of the stress in a zone 1″ high passing

through point 12 by the formula $T = P \frac{d}{2}$, which is the formula for tension in hollow cylinders subject to internal pressure, see Table III. The same operation is repeated for points 11, 10, 9, and 8, the horizontal stresses becoming smaller and smaller until between points 8 and 7, our thrust curve crosses the pressure line and becomes negative. (See Fig. 2). From this point to the crown the horizontal stresses represented by the stress diagram are only taken as criteria upon which to base judgment and modify intuition, since it is believed that the actual stresses are indeterminate; distributing themselves through an infinite number of arches and at the same time probably producing flexure as in slabs of small span.

The stresses due to wind pressure, were next taken up. Table II, which explains itself as the normal wind loads on the dome, may be considered as applying both horizontally and vertically—that is, the normal wind load at any point might be represented by that part of a radius of the sphere extended and comprehended between the inner and outer surfaces of the solid

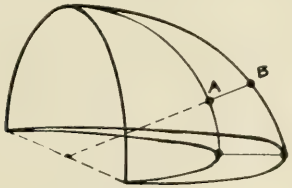


Fig. 5.

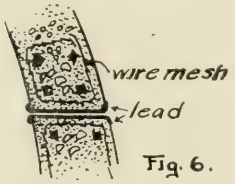


Fig. 6.

(Fig 5.) The meridian plane which divides this solid into two equal parts, was the one considered, as it evidently contained the maximum forces. Here again the diagram for the stresses on the windward side was considered of little value, but the resultant of the wind pressures produced bulging stresses on the leeward side, the nature of which it was thought best to look into. A study of the reinforcement (Table III) shows the result of the investigation. It will be noticed in this table and also in the diagrams of vertical reinforcement, that considerable more steel was used than the stresses seem to warrant. This may be explained as a means of accomplishing three things beside taking care of the stresses an indicated by the stress diagrams.

First. To form a network of reinforcement which would tend to collect those indeterminate stresses in the shell, and resolve them along lines which have been investigated and provided with sufficient reinforcement.

Second. To bind the shell together in a monolithic unit,

bridging over the inequalities of stress and strength of material, and

Third. To supply the needed resistance to thermal stresses. Referring to Table III, the horizontal reinforcement near the extrados of sections 1, 2, 4, 5, and 6, and that near the intrados of sections 8, 9, 10, 11, and 12 is provided solely to accomplish the three purposes above mentioned. All other bars are expected to act in this capacity in addition to the especial purposes mentioned below.

The ⅜″ bars in section 2 aside from this, serve in connection with vertical rods No. 3. (Figs. 3 and 4), to resist the bulging stress on the leeward side due to wind loads. The horizontal rods near the intrados in sections 1 to 8 in connection with vertical rods No. 1 are designed to resist those stresses due to dead weight and windward wind previously spoken of as producing flexure as in slabs. Those rods near the extrados in sections 7 to 12, in connection with vertical rods No. 5 and 2, resist the bulging stresses; while vertical rods No. 4 might be called into action on the windward side by flexure due to wind. The four heavy rods in the bottom were a precaution against thermal stresses, or damage resulting from settlement or deformation of the supporting structure. They were surrounded with wire mesh to avoid chipping. The whole dome rested on a smooth joint made of two sheets of thin lead, allowing it to expand and contract freely along radii of the plane of the base, but provided with six notches also radial, which prevent any chance of dislodgement. (See Fig. 6.)

The design of the forms was a very interesting part of the work but cannot be described in detail. The inside form which was supported from the ground, was built in the usual way, of joints and of ⅞ inch stuff, and staid with cross members of wire. It was covered outside with rosin sized paper and provided with an eight foot opening in the top, through which the material was hoisted. The inside of the outside form was a cylindrical surface of sheet iron about 3′x25′ in size with a radius equal to that of the extrados. This surface was backed by 1″ lumber, which in turn was supported by a rigid frame of joists. The form was hung by a chain at its center of gravity from a boom swung from a mast on the material hoist.

Owing to the dryness of the climate, the ample ventilation in the top of the dome, and the precaution taken in waterproofing the shell, no trouble was anticipated either from moisture without or condensation within, and the decorations were designed to be applied directly to the inside of the dome.

EXPERIMENTS BY THE FOREST SERVICE.

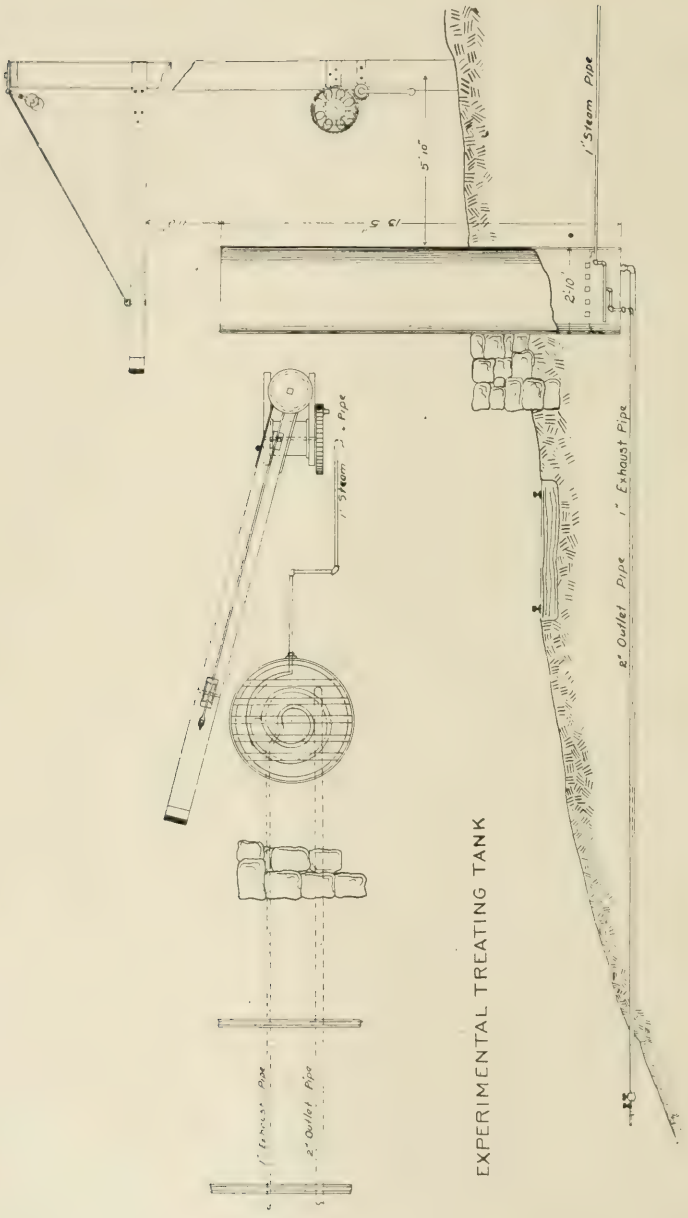
R. C. Wagner, C. E., '09.

Wasteful methods have had their day. The utilization of the odds and ends in by-products has become a recognized feature of all industry. The same idea is now being applied to nature and especially to the timber resources. The increased use of cement which has attracted attention on every hand, and the steel framed sky scraper which uses large quantities of fire proofing materials have not decreased the demand upon the forests.

Timber values have increased so rapidly during the last four years, and the better woods have become so scarce that they must be replaced by cheaper and more abundant ones. In order to bring about a more extended use of the cheaper woods the Forest Service has established a very effective experiment station. The results of previous experiments point to the necessity of the use of some preservative treatment of the inferior woods.

The practice of preserving timber by impregnating it with antiseptics is spreading rapidly in the United States and is recognized by both engineers and business men. The preservative treatment of railroad ties and piling has been practiced for a number of years and the treatment of mine timbers, posts, and telephone and telegraph poles has met with an enormous recent development. From time to time experiments have been conducted by various telephone, telegraph, and railroad companies, but either the treatment was faulty or insufficient records were kept, and, as a result, neither reliable data nor satisfactory conclusions were available. That treated wood is more durable than green wood in contact with the ground is generally admitted, but the many conflicting statements as to the value of a preservative treatment caused the Forest Service to determine what treatments are most effective and what expense for treatment is justified by the resulting increased service. Most of the processes in general use require elaborate and expensive plants, consisting of closed retorts capable of withstanding high pressures, of vacuum and pressure pumps, steam boilers, and fittings. The interest on the investment and the cost of operating make it impracticable in most cases to use such plants for the treatment of timbers which are required in large quantities and at comparatively low cost.

The great demand for some cheap and simple process of wood preservation gave rise to the open-tank method originated by the Forest Service. Its general adoption will largely increase



EXPERIMENTAL TREATING TANK

the amount of timber artificially preserved and so result in a great saving of the timber supply. It will insure a more complete utilization of the forest products, and encourage the use of quick decaying woods, instead of the less abundant high grade woods. The open-tank method is based upon the use of an open-tank, capable of withstanding heat, and equipped with steam coils. Plate 1.

The preservative, usually creosote, is run into the tank to cover the portion of the timber which is to be treated, and the temperature of the liquid is then raised slightly above the boiling point of water, 230° F. This temperature is maintained for a length of time depending upon the character of the wood and the treatment desired. At the completion of the hot bath the timber is either quickly transferred to another tank, conaining a cold preservative in which it is submerged for a definite period of time, or else the heat is shut off, and the timber allowed to remain in the cooling liquid.

The theory of the open tank process, as explained in Forestry Circular No. 101, may be given in a few words. The heat of the preservative expands and expels a portion of the air and water contained in the cellular and inter-cellular spaces of the wood tissue, and as the preservative cools there is a contraction and condensation of the air and water which remain. To destroy the partial vacuum thus formed the liquid is forced by atmospheric pressure into the cellular and inter-cellular spaces, a process aided, of course by capillary attraction. In point of fact, therefore, the hot bath merely prepares the wood for absorbing the preservative, and the actual impregnation follows as the preservative cools.

The ease and effectiveness with which timber can be treated by this process depend upon the kind of wood and its degree of dryness. In one species the structure of the wood tissues may resist, and in another favor, the expulsion of air and water during the hot bath; in seasoned timber, air, and in green timber, water, is the chief element to be removed before the wood can be treated, and since air may be expelled much more easily than water, seasoned timber is the more successfully treated.

Recent experiments of the Forest Service have demonstrated the open-tank method to be applicable to the treatment of fence posts, piling, and mine timbers. In conducting these tests the Forest Service secured the hearty co-operation of companies concerned with the timber supply. The Southern Bell Company set six hundred open-tank treated poles in a portion of a toll line near Savannah, Georgia. This region was selected primarily because of the rapidity with which timber decays there. The American Telephone and Telegraph Company set open-tank treated poles along a line in the vicinity of Buffalo, N. Y., which runs

through a varied country and allows an excellent opportunity to study the effects of various soils on the life of timber. Great care was exercised with all details of the seasoning, treating, and setting of the poles in each line and the nature of the soil, so that the results should add much to future knowledge of the seasoning and treatment of timber by the open-tank process.

The Forest Service in co-operation with the Reading Coal and Iron Company, planned and carried on a series of experiments to determine the best methods of prolonging the life of mine timbers. As a direct result of these co-operative experiments, the company is to treat mine timber on a more extensive scale. Plans have been drawn for a commercial open-tank wood preserving plant large enough to treat all timbers at its colliery.

In the construction of new track and for renewals the railways used, in nineteen hundred and six, over one hundred million cross-ties. Ten per cent. of the ties purchased were treated with preservatives either before they were purchased or at the treating plant of the railroad company. Careful records are made of the service given by the treated ties under different conditions and with the various methods of treatment.

These wide ranged experiments under actual conditions of service are being rapidly developed, and it is probable that future experiments will establish the open-tank method of treating wood. The saving by this method is readily apparent. Not only is the cost of operation and maintenance slight, but the cost of installation is less than that of the cylinder-pressure type of the same daily capacity.

When these tests are complete the results will be published from time to time and placed at the disposal of the public.

The Forest Service has just established a laboratory at Washigton, D. C., for investigating the structure of commercially important woods. A work of this character has long been in demand by engineers, architects, builders, and other users of lumber, who in these days of growing scarcity of the more valuable woods are seriously perplexed in identifying substitutes. Common woods are growing scarce, and woods not often cut prior to this time, are appearing in the markets. Many of these woods look alike, even to trained eyes of lumbermen, and yet they are very different in value for different purposes, and it is of the greatest importance to be able to distinguish them quickly.

The laboratory has been established in order to meet such needs. The structure of the woods, sections lengthwise and crosswise, will be studied so as to separate, by structure alone, the various species of a genus. Analytical keys to the trees of each group will be worked out. These will be based on the arrangement and character of the pores discernable to the naked eye,

or by the use of the hand lens. The important groups of wood, such as oaks, pines, and firs will be studied and the results published separately from time to time with good illustrations.

TESTS OF HICKORY.

The enormous resources of the United States have offered almost unsurpassed opportunities for industries to thrive, but during the last fifty years important economic changes have occurred, and now some of the industries which have prospered in the past have reached or are rapidly approaching a point where they must struggle for very existence.

This is especially true of certain industries which depend upon the hardwood supply of the country. Carriage-makers and manufacturers of farm implements, as well as those engaged in a number of other industries which are concerned in the use of hickory, will follow with interest a series of tests of this valuable wood about to begin at the Forest Service timber-testing laboratory.

The importance of these tests lies in the fact that they will furnish accurate data, on the relative strength of the different kinds of hickory, which is a wood for which no satisfactory substitute has been found. The hardwood forests of the northern section of the country are being rapidly denuded and it is important that accurate information regarding like species in other sections of the country be obtained.

The hickory of the northern states has always been considered of better quality than that of the south and has been quite generally given the preference by manufacturers and users of this species of wood. Prejudices once established are not easily removed and because of this fact, the Forest Service is preparing to prove the relative merits not only of hickory of the same species obtained in different sections of the country, but also different species of hickory grown in the same section. It is intended later to extend this work to other species of wood in the order of their importance to the manufacturing interests of the country.

Southern hickory was collected by a representative of the Forest Service and accurate data regarding species, growth, and locality were taken for each tree from which material was obtained. Other material of the same species, to be selected, will be treated in a like manner and all will be tested for the purpose of determining their strength, stiffness, and suitability for the purposes for which they are used. The strength, stiffness, and other data obtained by these tests will make possible a direct comparison of the merits of the wood as regards its species and locality of growth.

The importance in this first series of tests lies in the fact that they will determine just what species of hickory are strongest. Not until it is accurately determined just what species produce the strongest timber, will it be possible to know just what trees to plant. When the reports on the tests are completed, information on the work will be gladly given to all who write to the Forest Service at Washington.

GYPSUM PRODUCTS, AND THEIR ARTISTIC USES.

N. A. Wells, M. P.

The use of gypsum has been known to the arts since the earliest times. It was used by the Egyptians as the finishing coat to cover the masonry of most of their temples, both inside and outside. It served as a white ground for their incised hieroglyphics and ornaments. It is the base of the stucco ornament which decorates the Alhambra and many other Mohammedan structures throughout the Orient, and is in quite as common use today as in the most glorious epoch of Saracenic supremacy.

Gypsum has the great advantage of being cheap, easy to cast, mould, or carve; of a pure and even whiteness that readily takes any coloring matter without danger of chemical disintegration. It may be colored upon its surface or throughout its body. The fact of its swelling very slightly upon setting causes it to reproduce with perfect fidelity the minutest details of surface texture in the making of moulds from natural objects or works of art.

Its disadvantages are its friability and ready disintegration under the action of water, dampness, high and low temperature. Its great porosity renders it arid of moisture and its surface is easily soiled by dust or contact. This texture also makes it opaque in color, entirely lacking the lustre and translucency of marbles. Without some surface treatment its color always remains chalky and lifeless. Its many great advantages, however, have always made it a most desirable and valuable material in the arts, and have inspired much inventive genius in the effort to overcome its serious disadvantages.

The best collection of published formulae and technical methods now employed in the working of gypsum are to be found in William Millar's book upon "Plastering, Plain and Decorated," published by Batsford of London. In it one will find not only some historical account of the material, but careful and detailed directions for its employment in the arts. There is an appendix containing formulae of quantities to be employed for various kinds of work, together with many of the most valuable recipes for treating the gypsum chemically and mechanically in order to overcome or correct its disadvantages of friability and porosity. These difficulties arise out of the nature of its chemical constituents and their mode of combining, and the ease with which this combination is affected by temperature and moisture.

Gypsum, the hydrated sulphite of lime ($Ca\ SO_4\ 2H_2O$) is of frequent occurrence in various rock formations, especially in the Tertiary deposits. It is found the world over. In its natural

state it is known under the names of selenite, a transparent crystal; or satin spar, a fibrous opalescent rock; and as alabaster when it occurs in large rock masses of milky white or gray color. It was this form of gypsum which was so much used by the ancient Assyrians for the bas-relief sculptures of their palaces. One of the finest deposits of white alabaster is found in Italy near the city of Leghorn. Gypsum is also found in large quantities in Nova Scotia, New York, Virginia and Michigan. It finds its greatest use as a plaster, which is produced by burning the crude rock in kilns at a temperature of about 250° Far., after which it is ground to a powder. It has acquired the name of "Plaster-Paris" from the large and excellent deposits around the city of Paris, France, where it came to be of very general use as early as the seventeenth century.

It owes its valuable property as a cement to the fact that the water driven off by the heat of burning is readily re-absorbed by the dehydrated powder, becoming a fluid paste which admits of being poured into moulds where it soon hardens, or "sets." The fact, however, of its friability and that it so readily disintegrates under the action of water makes it a poor material for situations in which it must be exposed to the weather or subjected to any wear from possible abrasion.

If these weaknesses of the material could be overcome, "Plaster-of-Paris" would then become one of the most useful materials known to the arts. Among the most successful efforts yet attempted are those which have resulted in the production that is known as "Keene's Cement," an English product, and "Adamant Plaster," the result of an American invention. Keene's Cement is produced by plunging hot calcined gypsum into a strong solution of alum, and then drying and recalcining and grinding to a powder, which sets more slowly than ordinary plaster-paris and with a much greater hardness. This makes it a very good and suitable material for interior wainscotings, door casings, panelings, etc., but it is not sufficiently insoluble to withstand the weather. The same is true of Adamant, whose fabrication is jealously guarded as a trade secret, but which is plaster-paris treated chemically,—it may well be with borax in place of alum, since this will harden plaster in much the same way as does alum.

The writer has tried many experiments with both of these substances and with varying success, in an effort to produce a material which shall be more economical and at the same time more facile to work with than glass and ceramic enamels in the execution of interior mosaic wall decorations.

For many years the Vatican at Rome maintained a manufactory of ceramic enamel to supply the demand for pictorial and

ornamental mosaics, primarily in the church of St. Peter's at Rome, and in the more costly churches of Europe. Owing, however, to the cost and difficulty of working, this enterprise was recently abandoned. There are factories in Venice, however, which still produce this kind of work. The Tiffanys and the Lambs of New York, are the two firms in this country most widely known for their glass mosaics. In a conversation not long since, the writer was assured by Mr. F. S. Lamb, one of our experienced American artist decorators, that the old process of glass mosaics is too slow and costly in both time and materials to ever come into any general use in an age of hurry and high wages like the present.

Not being willing to relinquish the much desired qualities of glorious color, precious texture, and monumental durability which characterize the technical process of mosaic painting, the writer has continued a series of experiments in an endeavor to secure as far as possible the above mentioned qualities and at the same time eliminate that in the process which makes it both slow and difficult.

As a material, glass is both hard and brilliant, as well as translucent in color, but it has a glitter of surface whose reflection interferes with the effect of the whole when seen from certain angles of direction. The varying thickness of the glass often lifts different pieces at slightly varying angles on the surface, causing isolated and scattered points of glitter which interfere with a quiet unity of effect. Again it is difficult to obtain in glass a full chromatic scheme of tints and shades of all possible colors without very great expense. Again, the glass is so hard that it costs too much time and labor to cut it into the necessary small bits required.

Plaster, it would seem, offers certain distinct advantages of a technical character, among which are the ease with which it can be colored throughout its body by many of the metallic oxides and mineral earths while it is yet in the fluid state; also the ease with which this colored fluid plaster may be cast into flakes of an even thickness and smooth surface by simply pouring it out on large sheets of glass and pressing down over it other sheets of glass sustained at a given height by small bits of broken glass placed between the two sheets. In this way we get, in a few moments, material whose color is any desired shade or tint, and whose surface is perfectly flat and smooth *without glitter*; but it is also porous, holds dust and dirt, is easily soiled, and is not sufficiently hard to be of a durability sufficient to stand necessary cleaning; it also dries out chalky and almost colorless.

To overcome this difficulty many experiments were made, among them that of immensing the dried flakes in strong hot size.

or glue water. This filled the pores of the plaster and restored the color; it also gave the required hardness and resistance to abrasion, but it left the material a prey to dampness which disintegrated the glue.

To overcome this difficulty the further experiment was tried of treating the glue sized flakes to a hot alum bath which made the glue insoluble. This proved successful, with the exception of the blues and greens whose color was attacked by the alum. This treatment also served to rob the flakes of their delicate surface and make the colors somewhat heavy and lifeless. Furthermore, so many processes became costly in labor and time.

A better result was obtained at the cost of a single supplementary process by plunging the flakes into boiling parafine, which not only filled the pores of the plaster but actually dehydrated it if the flakes were left in the hot parafine sufficiently long. The result gave a richness and semi-translucency of color, and a complete protection from moisture, yet the material lacked something to be desired in the matter of hardness to resist ordinary abrasion. The boiling in parafine also consumed much valuable time and material.

One further experiment was made through the kindness and aid of Professor Parr of the Chemistry Department, which resulted in the production of a material having much of the characteristic appearance of marble, retaining a fineness of surface texture, a full saturation of color, and an increased hardness sufficient to resist ordinary scratching and abrasion. At the same time the flakes could be easily "scored" with the point of the knife and broken into any desired shape or size.

All that was necessary was to dip the dry colored plaster flakes into a cold chemical bath and let them dry slowly in a moderate temperature. The chemical bath can even be applied to large surfaces with a brush or sponge, in which case the treatment should be continued until the pores are filled and will absorb no more. There are a number of chemical compounds which will serve the purpose but the one employed in this particular instance was *borate of ammonia.*

The Department of Architecture is now in possession of a complete stock of colors made of this material from which the pieces illustrated in this article are composed.

The ancient technical process of "laying" mosaics consisted in embedding the bits of colored glass or ceramic material in hydraulic or other cement upon a roughened plaster ground. Usually the plaster ground was laid upon a wall of masonry, brick, or stone.

In these modern days it has been laid upon a foundation of expanded metal, and even upon wooden laths. It is not, how-

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ever, with these foundations that we are immediately concerned; suffice it to say in passing that all really monumental work should be constructed of durable, and, as far as possible, fire proof materials, from foundation to surface finish.

The old method of "laying" the mosaic *in situ* upon a roughened plaster surface, necessitated covering the foundation surface with a smooth finishing coat of soft cement into which bits of colored glass or ceramic were pressed with the fingers, care being taken to keep the surface as level as possible and the pieces of equal height.

It is obvious that only so much of the finishing cement should be laid as could be covered before "setting,"—that is to say, as much as could be covered with mosaic in the space of a few hours. The process is of necessity a very slow and tedious one. many devices have been tried to reduce the labor and difficulty of the *in situ* process.

One method is to lay the mosaics in sections of a foot or more square in a bed of cement thick enough to handle, and then assemble the sections together in their proper order and "set" them upon the foundation just as tiles are set.

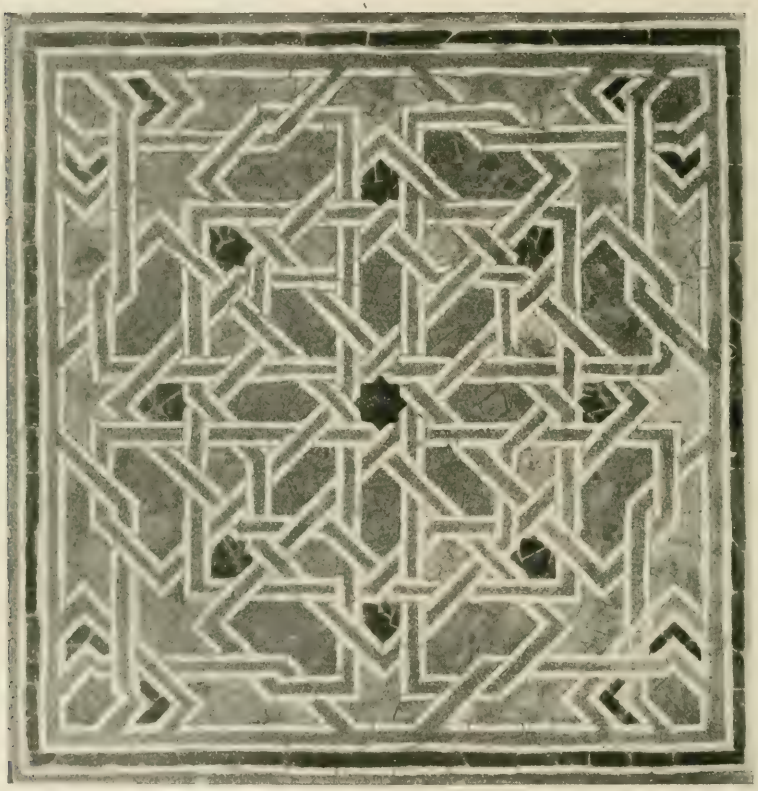
This method is not so very difficult where the surface is a level one; but where a covered surface, like that of vaulted or domed ceilings is in question, the process becomes difficult, tedious, and costly. The chief artist of the *Tiffany studios* informed the writer that he took sectional plaster moulds of the entire surface of the ceiling in the delivery room of the Chicago Library and transported these moulds to the New York studio where the mosaics were laid in sections upon the moulds. These were then sent to Chicago and there placed in position. It becomes obvious at once that such a process is too costly for any undertakings but those of unlimited financial resource.

Having found a colored material of reasonable cost, easy to work and yet of sufficient durability, our next step was in the direction of reducing the labor and difficulty of "laying." For small, or moderately sized works the following is a suitable process.—

Let the full sized design be traced in outline, or even be executed in color, upon paper or canvas. Upon this lay a stout sheet of glass large enough to cover the entire design. The bits of colored plaster are then laid face downward and attached to the glass by means of beeswax softened with lard oil. When the design is all laid, a dam of wooden strips $\frac{7}{8}$" thick is laid on the margin of the glass and also fastened in place with wax. Plaster-paris is then poured over the whole, a piece of "burlap" canvas embedded in the back, and when fully set, the sheet of glass is removed from the design by suspending over a stove, hot air radi-

ator, or hot air flue, until the wax melts, when the panel will easily slide from the glass. The mosaics may be easily cleaned of wax with gasoline, and the interstices not completely filled with plaster can be filled up by rubbing them over with stiff putty. The panel may now be set in a wall or framed.

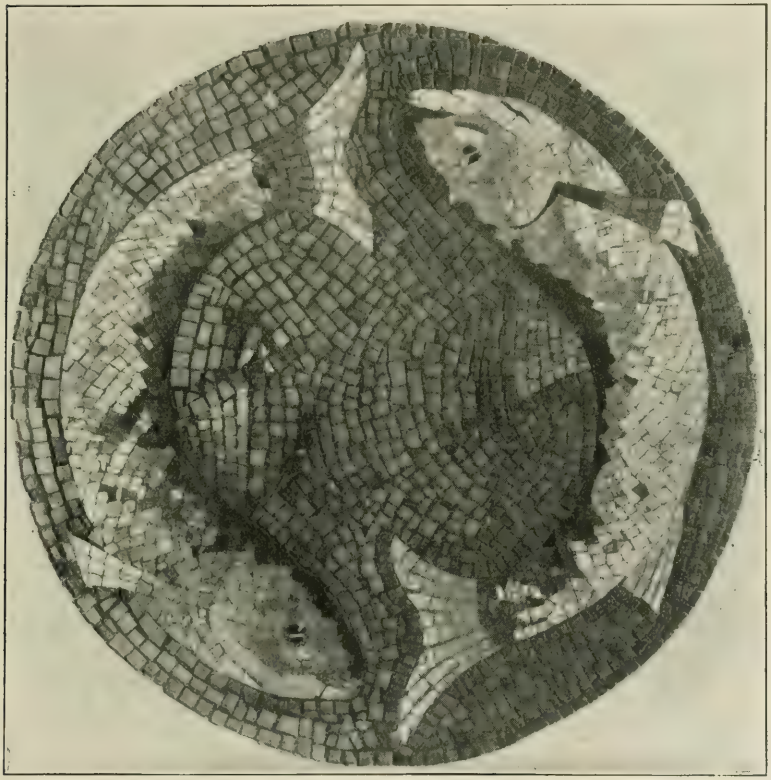
The designs accompanying this article were executed in this manner. The "fish" design is intended to be set into the front



of a marble altar for an Episcopal church. The Moorish design is to be let into a small table top. The four slabs of inlay for the mantle facing were executed by the writer in a single afternoon, and the whole has since been hardened by the application of the borate of ammonia solution until the facing is quite like marble in hardness and texture. Slabs of this kind can be made as large as plate glass can be found on which to lay them.

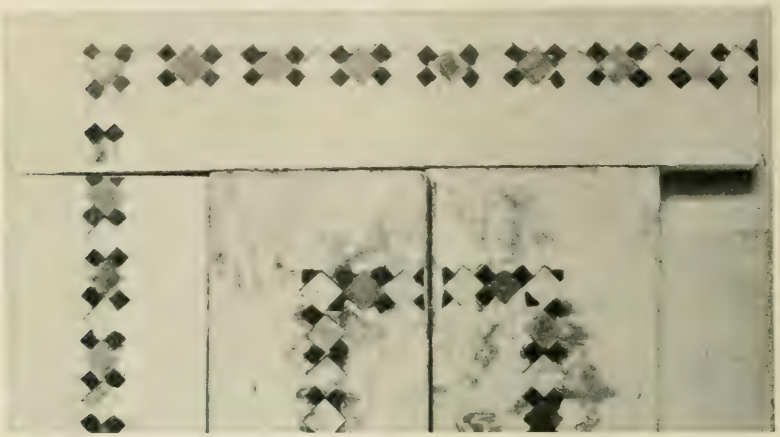
It now remains to describe a process to be employed in the decoration of large and irregular surfaces, such as ceilings, vaultings, lunettes, panels, etc.

A smooth trowel finish,—the "white hard finish" of the plaster lends itself most readily to the process. If the danger of cracking is feared, the plaster should be covered with cotton "factory" laid in a mixture of lead, whiting, oil and a little varnish. This should afterward be covered with a stiff coating of the same mixture. Where plaster panels, vaultings, or ceilings are laid upon



expanded metal and there is no danger of cracks, this cotton covering can be dispensed with and the plaster simply "primed" with white lead in boiled linseed oil. So soon as the surface is ready, the design may be executed upon it in ordinary decorator's oil colors; fresco gilding may also be added when that is desirable. In this way all experiments may be made until the right "key" and "tonal harmony" are found. The whole may now be incrusted with the colored plaster cements and gilded glass grounds, as the case may require,—it being only necessary to match the painted and gilted portions with corresponding col-

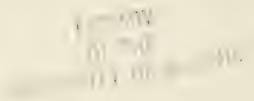
ored cements which should be attached to the surface by a strong mastic varnish being laid over the work, a small portion at a time, as it dries very rapidly.



In this way any surface may be decorated with a mosaic which is sufficiently durable for all purposes except that of the pavement, and at a mere fraction of the cost in time and material required by the old process.

Those interested in this kind of monumental decoration may find examples of it now being executed in the studio of the Department of Architecture for the chimney breasts of the Faculty Club House.

This Night at least
Forget thy Care and



THE ARCHITECTURAL ARTS.

M. B. Cleveland, Arch. '08.

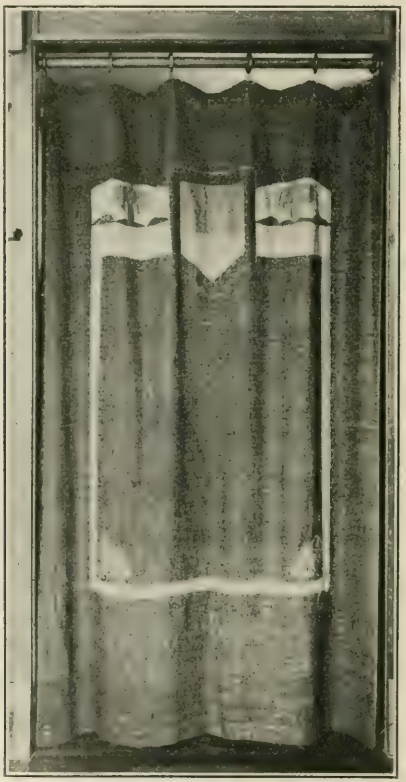
Of the Fine Arts—Architecture, Painting and Sculpture —Architecture is now recognized as being one of the first in importance and is the most fully developed of the three in our country. Since the beginning of time man has fashioned abodes to protect himself from the elements; the tree house of the Tropical man or the cave of the Cave Dwellers was a beginning. As man advanced in the scale of civilization he required finer abodes, until at the present day the buildings he erects to house himself or his interests are magnificent and varied in use. The Cave Dweller decorated his hut with crude carvings, but the buildings of today must be decorated with beautiful mural paintings, marbles, mosaics, stained glass, wood carving, metal work, and many other inventions of man's artistic genius.

All this has given birth to a new branch of art which is usually spoken of as Architectural Art and has to do with the decorative embellishment of buildings. Thus we have created a demand for the very highest artistic skill in these several lines of decorative art, and our great Universities, Technical and Art schools are providing means of specialized education in these lines. So with our gains in wealth and culture there will be further demands for our artists. Never before in the history of our country was the outlook brighter than now—for the architect, artist, and decorator.

Every architect must know and appreciate the artistic side of his profession fully as well as he does the constructive side, else his buildings must be mere shells—eminently fitted to withstand wind pressures, and moving loads but totally incapable of calling forth that higher aesthetic feeling which is really one of the desired ends to be attained. This fact is now generally recognized in large offices by the employment of especially trained designers as well as engineers. On large commissions the decorative work will be done, each part by a man who is especially skilled in his particular line. But for the small commission it is usually impossible to employ an expert artist to carry out each part of the work and then there arises the need for a man in the office who can work intelligently and with a certain amount of artistic feeling to take charge of the work and carry it out. It is especially desirable that the designer of the building be able to do this himself as then there will be a feeling of unity in the completed work which is sometimes so evidently lacking unless the work is carried out mainly by one mind. If the architect himself is trained in the principles underlying this, he can usually direct any small work to a satisfactory completion.

We are thus impressed with the importance of the Architectural Arts to Architecture in particular and through that to the great

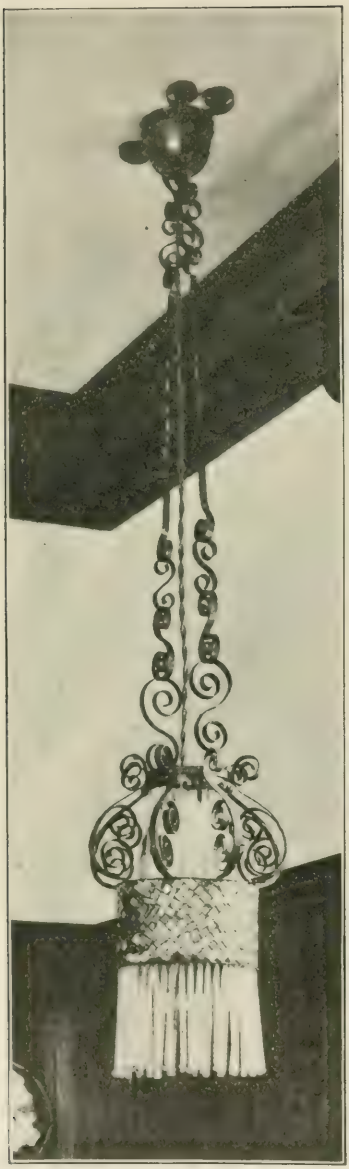
mass of the American people in general, to whose higher aesthetic nature we are making an appeal, for only as we arouse the cultural wants of the people can we raise the standard of living—which is really the end of being. It is with a feeling of great satisfaction then that we realize that our own University has been one of the foremost in recognizing this new trend of feeling, and has established a course in its Architectural Department which gives the student specialized



training in the designing of interiors, exteriors, and the several branches of the decorative arts. This is the course in Architectural Decoration and leads to one of the regular University degrees. This course, as in fact any course in Art or Architecture should, contemplates a thorough knowledge of Free Hand drawing as a basis, and work in that line forms an important part of the first two years' work, as also does Language, Rhetoric, English and other aesthetic subjects. With this work a study is made of plant and animal life from nature and then artistic anatomy is taken up and carefully mastered.

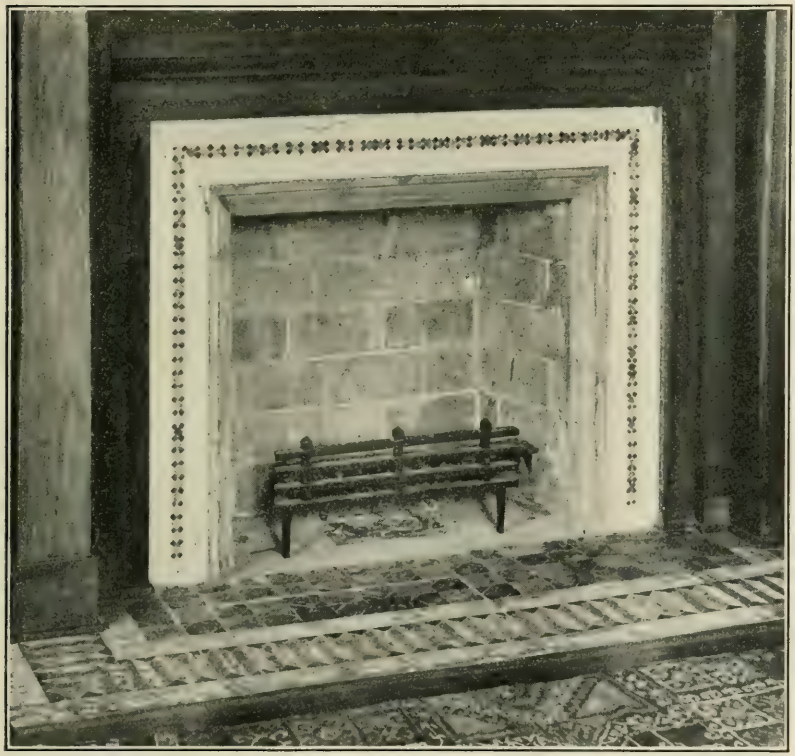
The theory of color, as the basis of all work in color, is thoroughtaught and illustrated with plates executed by the students. The psychology and visual impressions both as to form and color characteristics, is carefully studied and various tests are made. With this as a foundation the Historic Styles of Ornament are studied, by means of diagrammatic plates on which the student works out examples of ornament, stained glass, mosaics, etc., in historic forms and coloring. In the design of decorative ornament, which is taken up after the student is familiar with color theory, he is given the problem to design the decorations for a given room. A spray of

grape vine with fruit and leaves may be chosen as a motif; this he studies carefully, and freehand and color sketches are made illustrating its form, texture and color. He is then required to apply this to the decoration of a dining room. The treatment is unrestricted and he may conventionalize or treat it naturally as suits his fancy. After his designs are completed, full sized stencils are made if the work is to be in stencil, or full sized cartoons if it is to be freehand. Instruction is given in all processes as the work progresses, until the ornament decorates a wall. The student prepares his own stencil



paper or transfer carbon and mixes his paint in oil or distemper as the case may be. Fig. 1 shows an original design for the Dining Room decoration for the New Faculty Club House, executed by a member of the class in Mural Decoration.

The possibility of mosaic effects for both exterior and interior decoration are great and an important course in this subject takes up considerable time in the third year. Mosaic work may be executed either in glass, plaster, or ceramic tile. In such work the



student makes the preliminary sketch for his design, which after approval, is developed into the complete full sized drawing. This is covered with a sheet of glass on which the bits of mosaic are laid in wax. Upon completion a sheet of cement is cast over the entire design and it is lifted from the glass. Such mosaic work may be laid on canvas which has been cut to proper shape and in this way curved and irregular surfaces may be covered. Or the mosaics may be encrusted in lead on iron. Fig. 2 shows a chandelier designed and executed by Prof. Newton A. Wells for his residence. It is of metal encrusted with mosaics; strap iron and glass. The effect is charm-

ing, the color being Byzantine in character. An article in this issue of The Technograph by Prof. Wells treats this particular branch in which he has made some important investigations, in a complete way. Illustrations of the work will also be found. Work in the designing of textiles and rugs is taken up. Fig. 3 shows a hanging designed and executed in this course. Fig. 5 illustrates an original design for a rug now being executed by a pupil of the school.

Wood carving, metal work, modelling, and etching are taught, the student learning the use of the different tools and materials and by acquaintance with the processes and theory involved, and the actual performance of the work, gaining a thorough understanding of the subjects. Fig. 4 illustrates a bit of wood carving designed and executed by Prof. Wells for his home.

The criticism of art is taken up by means of illustrated lectures, and carried through one year. Modelling in wax and clay is studied and many designs have been made and executed in these classes. The Sun Dial—the gift of the class of '06, is being designed in this department by Mr. Joseph McCoy. Figs. 6 and 7 illustrate colored plaster panels modelled in this course. Various designs have been etched and executed by the students and the Architectural Club recently issued an annual, which was entirely executed on the press of the department. In this way original designs of the pupils are disseminated in the community.

Other lines of work are studied all of which have to do with the decoration of architectural objects. Such a course is of the greatest value to the future of artistic work in this country. It is manifestly of the greatest importance to educate the mass of the people to artistic feeling and it cannot be done by confining the work of decoration to a few great hotels, libraries or other public buildings, as well as by appealing to them in their home life. A nation cannot be called truly artistic where its works of art are confined to a number of great buildings. Such a condition shows a desire for display much more than a demand for art or a memento of individual effort. When our people as a mass demand homes of artistic design, filled with beautiful things selected because they are beautiful and not because they are costly, surrounded by charming lawns and gardens, where the feeling is evidently for beauty rather than for display so crudely in evidence, then and not until then can the individual laborer for better things cease his work. This applies as well to the working man's cottage as the millionaire's palace, which often, by the bye, is the most ostentatiously displeasing of the two.

There has been a great advance of late along the lines of beauty in suburban architecture and much is being accomplished in artistic decoration of the small house, and it is for our Art schools and Universities to keep such courses before the people and by sending out trained men and women in this field of work, to encourage the demand for simplicity and beauty which has succeeded already in gaining a strong foothold in this country.

PROGRESS IN THE ENGINEERING OF HEATING AND VENTILATION.

G. M. Brill, M. W. S. E.

The art of heating and ventilating has not received as much attention in our universities as its importance warrants. It is a profession just emerging from having been a sort of side line, and is worthy of a more dignified position. The demand for properly educated heating and ventilating engineers is increasing rapidly.

The temperature in which we live and the quality of air we breathe is parallel in importance with the food we eat and the water we drink. The importance of maintaining a proper temperature and providing fresh air should be impressed on each generation all through the years of education, and the furnishing to the world of engineers trained in this particular line is a crying need today.

The importance of proper heating and ventilation of schools is so well recognized that several progressive states have already passed laws providing and enforcing a standard, and other states are sure to follow. The necessity of proper ventilation is one of the tenets of the large and powerful organizations now striving to stamp out tuberculosis.

There are surprisingly few competent heating and ventilating engineers now practicing the profession. It is a broad and honorable calling. The country is awakening to the need of specialization. Aside from hygienic reasons the pecuniary loss each year on account of incompetent design of heating and ventilating plants is enormous. Many thousands of dollars are wasted is the adjusting or removal of improperly designed apparatus. The literature available on the subject is not voluminous. Most of our writers copy the tables of heat transmission developed by the experiments and tests made many years ago by German and French engineers. The American Society of Heating and Ventilating Engineers is now striving to build up a reliable mass of data and to apply the information in the proper way. Recent tests have shown the need of revolutionary changes in the design of heating apparatus which has for years been considered almost perfect.

The majority of residence heating plants installed in this country are designed by rule of thumb by the contractors who install them. No particular attention is paid to the quality of the construction of the building or to the normal direction of the wind or to the ventilation. A competent engineer could design for most of these residences, plants which would furnish reasonable ventilation, adequate heating, and economical fuel consump-

tion at no greater first cost than the ordinary plants and no expensive adding to or cutting down radiation, changing boilers, etc., would be necessary, as is often the case at present.

School buildings, churches, etc., are generally provided with heating apparatus designed without charge for the architects by the manufacturers of various appliances entering into them. By this method while plants are secured which usually are adequate, the specifications are unfair, calling for special appliances to favor the manufacturer' designs, and too often the computations are intrusted to some inexperienced draftsman. They invariably throw the entire responsibility for the success of the plant on the contractor, and the ignorant one who fails properly to allow for the expense of adjustment pays dearly for his experience. The "wise" contractor who does make such allowances, loses the work because his bid is high. Should the design of the heating and ventilating of our public buildings affecting the health of our children be intrusted in such hands? There are, of course, exceptions to the above rule, and I am glad to say that the equipment of schools of probably more than half of our large cities is under the supervision of properly educated and experienced heating and ventilating engineers.

Our theaters, churches, court houses, jails, stations, hospitals are free to do as they please, and absolutely no ventilation and inadequate heating is a common result.

Our modern office buildings are almost invariably designed by well educated architects, who employ specialists in the design of all of the various parts, and the buildings are usually adequately heated and ventilated—not perhaps because the owner believes ventilation necessary, but because a well equipped building has proven a better financial investment. The heating and ventilation of any building containing and operating its own power plant is usually well designed, the desirability of preventing back pressure on the engines being the prime motive.

I know of one building beautifully ventilated, the entire heating being indirect, because of power requirements giving a large volume of exhaust steam which it was economical to use for heating purposes. In most buildings the heating apparatus requires considerably more steam than the power plant exhaust furnishes. It is economical to use exhaust steam for heating, because the returned water of condensation is usually nearly as hot as feed water heated by the exhaust would be.

The heating and ventilating plants which give the best results in cost of installation, operation, and appearance are those designed in the architect's offices; and developed along with the building plans. With both factors thus elastic, a perfect unison is obtainable. When on the contrary, fully developed building

plans are sent the heating and ventilating engineer, the basement apparatus, flues, radiators, etc., have to be placed in inadequate or disadvantageous locations. Had earlier consideration been given to their necessities, a far better, more economical and lower priced installation could have been secured.

The quality of the buildings too often fails to receive consideration from a heating standpoint. The extra cost for fuel necessitated by reason of leaky window frames will pay for new ones in a season, in many instances. Thicker walls, building paper, false ceilings in top floors, particularly in concrete buildings, all should be considered. They seldom are. Usually the mistake is corrected by adding more heating apparatus and forever after burning more fuel.

The effect of the heating apparatus on ventilation is often ill considered. Everyone knows that a stove or a direct radiator pulls the cold heavy foul air from the floor, along with the dust and offal there and disseminates it into the atmosphere at the breathing plane. The condition of the wall above any radiator proves this. Thus a direct radiator defeats the ventilation of the room in which it is placed. Radiators in ventilated rooms should be used only when first warming them. The same amount of heat after that time, applied to warming the air supply, will maintain the temperature.

The direct radiator as ordinarily placed under the windows, loses above one-half of its radiant heat into the wall and so wastes it out of doors. Only enough direct radiation should be placed against the outside walls to prevent drafts from the leakage and cooling of the glass. I believe that with tight windows, the cooling effect of the glass would not produce noticeable drafts. It is well known that radiators placed in the center of rooms as in stores, are much more effective than those placed under the windows. The comparative cost of heating properly designed, all indirect heated schools, as against those heated by direct radiation with independent ventilation, shows in favor of the all indirect, by a large margin.

The only safe basis for designing heating and ventilating plants is the heat unit. This amount of heat will raise the temperature of about 55 cubic feet of air one degree in one hour

$$1 \text{ — HU will raise } \frac{1}{0.238} \text{\# of air } 1^\circ = 4.2\text{\#} \text{ of air } 1^\circ$$

1# dry air occupies 13.4 cu. ft. @ 70° $4.2 \times 13.4 = 56$ cu. ft.

The rate of transmission of heat from one body to another varies, a greater difference in temperature causing a more rapid transmission. The rate of transmission is thus affected by the movement of the bodies, a greater velocity of one over the other

bringing constantly cooler surfaces to be warmed, thus increasing the rate.

The determination of the amount of heat lost from buildings of various constructions, with or without wind, with varying temperature, inside and out, is thus a complex problem. Our data on this are inadequate, but we have tables which we know to be approximately correct within ordinary limits. In designing a plant, the first operation is to study the construction and compute the total loss of heat by multiplying the loss per sq. ft. per hour by the sq. ft. of each type of construction in each apartment. Then allowance must be made for leakage, and here judgment and knowledge of the quality of workmanship must be used. Then wind allowance must be made, for as explained above, wind on the outside of a wall or window, enormously increases the heat transmission and also the leakage.

Having determined the total heat lost—or in other words, that to be supplied; the amount of radiation, number of pounds of fuel to be burned, size of grate, number of pounds of steam required, or cubic feet of hot water needed, may be very easily found.

The sizes of the steam piping may be found from the amount of steam required and the size of the water piping from the number of cubic feet of water needed. The size of the boiler or heater, the sizes even of the hot air furnaces and piping, all should be reckoned on the heat unit basis with the heat loss from the building as the foundation for computation.

The details of this method are simple and the whole scheme is easily grasped. Nearly the whole process may be reduced to tables or charts. The element of judgment is of necessity important. Experience only can mature judgment, but if our mechanical engineers and architects were more thoroughly grounded on these practical details, the quality of our heating and ventilating plants would be much improved.

Compulsory ventilation of all rooms used for an assembly of people will, I believe, be necessary. It will not work a hardship if adopted in all new buildings as they are built and incorporated in all old ones as they are remodeled.

The supplying of 30 cubic feet of fresh air per occupant per minute is the minimum generally set by common practice and by law in those states in which it is mentioned. This should be the minimum, as even with this volume entering a room, one usually may perceive a marked difference between outside air and that in the room.

Ventilation may be upward or downward. If the practical details of construction did not render it difficult of installation in most instances, it is believed that upward ventilation would be

the more effective. For upward ventilation to be satisfactory, however, the entering air must be at, or close to, 70 degrees, and must be forced in through many openings in the floor not far apart and all over the room. The outlet is near, or in, the ceiling. The ascending current of fresh air carries with it the products of respiration. This method while expensive is almost imperative in large rooms lighted by open gas jets, or in rooms like theaters in which it is as important to keep the temperature cool after occupancy, as to raise it prior to occupancy.

It has been found almost impossible economically to cool rooms by downward ventilation, and many buildings using downward ventilation for heating are equipped with reversing appliances so that upward ventilation may be used whenever it is desirable to reduce the temperature.

Downward ventilation is based on an entirely different principle from upward ventilation and on account of the ease with which it may be installed, is used almost universally. It is successfully operative, however, only when the entering fresh air is warmer than that in the room. The cool and foul air being heavier settles to the floor, where it is removed and the fresh, warm, lighter air keeps supplying the deficiency. There is a constant settlement of the air in the room in nearly horizontal strata and the floor must always be a little cooler than the ceiling. The exhaust opening must be at the floor. The location of the inlet is not vitally important as the warm fresh air will rise at once to the ceiling in any event, but the inlet is customarily placed near, or in, the ceiling. The inlet and exhaust openings are preferably placed on an interior wall, near the vertical planes of each other.

The duct and flue velocities, and thus the amount of ventilation, are affected by the difference between the inside and outside temperatures, the amount of moisture in the air, and the wind. Thus natural or gravity ventilation is weakest when most needed. This had led to the adoption for all but small buildings of forced or mechanical ventilation. A single supply fan usually is sufficient though in buildings in which large exhaust flues are not economical, or for rooms like kitchens or laboratories, requiring excess ventilation to prevent dissemination of odors, both supply and exhaust fans are desirable and imperative. For all rooms except those in the kitchen class the supply of air is in excess of the exhaust, thus creating a slight pressure over that of the normal atmosphere, which tends to counteract the effect of the comparatively heavy outside air leaking in at windows and crevices. The temperature of the air admitted for ventilation must be carefully controlled. The automatic regulation of this temperature is almost universal. The admission of cold air through the inlet of a warm room would create a noticeable draft, as the cold air

would fall to the floor immediately. By aid of the automatic regulation we are able to change the temperature of the incoming air slowly, without changing its volume and so maintain the temperature of each room nearly constant.

There are several satisfactory and practical systems of automatic regulation. Compressed air is used as a motive force in nearly all of them. The air may be compressed by an electric or steam pump, by a compressor, belted or geared to the other machinery, or by a small hydraulic pump. All of these devices are in common use and all may be provided with automatic governors which throw the pumps out of service except when the air pressure drops. The standard systems of automatic regulation operate about as follows:

From a central air tank, small pipes lead to each room and then to each radiator or damper to be controlled. In each of these rooms is located a small valve called a thermostat which opens automatically and permits the compressed air to pass by and close the radiator valve or hot air damper, as the case may be, when the temperature in the room rises above the desired point. The valves and dampers are provided with springs or counterweights so that when no compressed air is admitted to them the heat is always turned on, thus providing so that should the regulation be inoperative there will merely be the possibility of an excess temperature. Thus systems of automatic regulation are merely devices to shut off the heat when the same is not needed, and therein lies their money-saving virtue. An appreciable advantage of plants equipped with automatic regulation is also gained by having a supply of compressed air always on hand which may be used for manipulating windows, dampers, etc., or even for running clocks and ringing bells.

We have devices for supplying humidity to the air automatically, to make up a deficit in the outside air or to replace that lost in heating.

A problem constantly increasing in importance is that of cleaning and purifying the air admitted for ventilation. Numerous air cleaners are in use. The dirt may be removed by them but they create excess humidity at times as water in large quantities is sprayed into the air. Mechanical devices remove the entrained water, and cooling coils in circuit with refrigerating plants condense on their surface much of the evaporated water. Nature gives us a hint in the hairs placed in our nasal passages, but we seem so far to have failed to approach nature in the efficiency of our air cleaners.

The details of the numerous systems of heating buildings or groups of buildings are legion.

For buildings occupied all of the twenty-four hours, the use of hot water as a circulating medium has great advantages, especially as the temperature of the water may be varied as required by the variations of the outside temperatures. The circulation of hot water being slower than that of steam, the latter is more favored for buildings which are occupied intermittently. The use of hot water under pressure, and hot water under circulation induced by mechanical means, as by pumps, overcomes the objection of sluggishness and is apparently growing in favor. For central station heating with forced circulation hot water is very economical and satisfactory, and is sure to increase in favor. Plants are in use in which steam, either live or exhaust, is conveyed to various sub-stations where its heat is transmitted to water circulating systems, and on account of the simplicity of installation and ease of temperature regulation, this arrangement has desirous features.

The advantages on account of regulation gained by hot water heating are approximated by circulating steam below atmospheric pressure. Other advantages of this system are the very rapid and positive removal of air, resulting in the quick warming of extensive and far-reaching pipes and radiators. The sizes of piping may be reduced and back pressure may be eliminated, thus increasing engine power while using exhaust steam, and this last advantage is the reason for the installation of vacuum systems almost universally in our large commercial buildings.

The greatest success is gained by using a positive exhauster to aid in maintaining the vacuum, with traps of one sort or another at the radiators which permit water or air to pass to the exhauster, but which prevent steam from passing. There is another type of low pressure heating rapidly growing in favor which depends merely on the vacuum created by the condensation of steam for its efficiency. There are hundreds of variations of the patented appliances used in connection with this type, but air tight piping, radiators, heaters and valves are essential, and in the present state of the art of steam fitting, absolute tightness is difficult to maintain.

A very large amount of heating will probably always be done with furnaces and stoves. The design of this apparatus is open to development and is susceptible to great improvement.

The effect of radiant heat has failed properly to be considered in many instances. A large part of the heat rays from any fire go straight up and through the top of the firebox. Steam and water heaters have circulating water there to take up this heat. The ordinary furnace has nothing, as the construction is of necessity such that air can not easily pass over this part. Unless ample and heavy surface of some sort to catch and be warmed by this escaping radiant heat is provided, the furnace will be inefficient.

Air is not appreciably warmed by radiant heat, but to be heated must be rubbed against some warm surface. The radiator or hood of the ordinary furnace is not effective nearly so much because of the heat of the products of combustion inside it as on account of the radiant heat from the fire below it, which it intercepts and transmits to the rising air currents.

With as much engineering ability applied to the design of furnace heating plants as is devoted to the design of apparatus of other types, the former give results in many instances equal to the latter. Furnaces are used for heating with fans blowing air over them, thus gaining increase in the heat transmission, and by the air pressure generated preventing any leakage of gases from the furnaces. Such plants usually are provided with devices which permit the firing of only as many of the furnaces each day as the outside temperature may require. Automatic temperature regulation may be applied to furnace heating plants either those with fans or those operating by gravity.

Various systems comprising combinations of furnaces with steam or hot water are in successful operation and in many buildings are very desirable as providing the lowest priced method of caring for all of the rooms. The greatest difficulty in operating these plants is the balancing of the two factors, so that when the furnace part is sufficiently warm the steam or water part is not over-heated. This trouble seems recently to have been solved by the placing of a coil of indirect steam or water radiation in the furnace air chamber, which acts as an equalizer, giving off or taking up heat as the conditions may require.

Coal is burned most advantageously and its heating value most economically extracted in large plants equipped with labor and heat saving devices, and operated by skilled attendants. The efficiency of such plants is generally so much higher than that of small units promiscuously attended that it far more than offsets the losses of extensive transmission systems. Therefore, it appears that the heating of the future will largely be done from central stations. This development is in its infancy but already there is encouraging progress. Generally it is desirable to centralize at the central station the electric generators, air compressors, refrigerating machinery, etc. The heating engineer has learned so to apply the apparatus in the various buildings that need of skilled attendance is largely eliminated. For instance, in a large school plant the heating coils may be elevated so that steam circulates by gravity, and fans are propelled by motors and there are no pumps, engines, traps, etc., usually a source of trouble in such a building.

The necessity of adaptation of the heater to the type of fuel to be burned is, apparently, not sufficiently considered in general

practice. An efficient soft coal heater seldom does well with hard coal, and with gas and oil, heaters adapted to either of the above may fail.

It appears that any fuel should properly complete its combustion in a sort of retort in which conditions are kept favorable, with a high temperature, and carefully regulated air supply. The fuel should be so introduced as not greatly to reduce the temperature of the retort at any time. The heating surface, which perhaps more properly should be called cooling surface, should not exert its influence on the actual fire but on the products of that fire. The observance of this general idea seems to be necessary in obtaining the maximum efficiency of the fuel and its combustion without smoke.

When I started this paper I hardly knew what to say. I now find it difficult to stop. I have not attempted to treat anything exhaustively. I have only hit a very few of the high places. There are cavernous depths practically unexplored, and there are many pinnacles well lighted by experience. I am learning more every day of how little I really do know. Within a year I may learn what will change my ideas on some of the few points on which I have here committed myself. The scope of the art of heating and ventilating is enormous. Volumes might be written on its progress, or even lack of progress, if you will, in connection with any one of a hundred vital interests.

I remember hearing once that "Lawyers nowadays have to study and study and keep studying night and day to keep up with the progress of their profession." The heating and ventilating engineer has to work as hard as the lawyer, and his profession has absolutely unlimited fields for exploration for the mind trained in the ability to reach out into the darkness and conceive improvements or new devices. The profession is following in the footsteps of its older brethren, the architects, the civil and the mechanical engineers in the organization of societies and chapters in which there is free interchanging of information, the members giving each other the benefit of experience, study and observation.

Some of our data are clouded by insufficient tests—some of our tests are not altogether dependable. We are looking for help in these matters from the well equipped and scientifically managed laboratories of our universities.

IS THERE SOMETHING WRONG WITH CURRENT ENGINEERING EDUCATION?

A. Brundage, C. E. '09.

If one has occasion to talk with an employer who comes intimately into contact with very many young technical graduates, he will find underlying his conversation a more or less strong current of dissatisfaction with the product of our engineering schools. Recently the writer was, to say the least, disconcerted to have a man whom he had barely met, launch precipitously into a sweeping indictment of the present day college man. He had under him some thirty or forty young fellows fresh from university, and he very vigorously prefered numerous serious flaws in their training, demanding of me as an undergraduate a defense. His indictment included lack of executive ability, a dislike of hard routine work, a lack of powers of expression, no initiative, and even indifference. He also indicated a feeling of discontent, in his own words, they wanted to become immediately, without serving their time in the ranks, captains in the great army of industry. Let us examine analytically our system of engineering education with an eye open toward the reasons for charges of such gravity.

Technical education in this country is barely out of its infancy; especially is this true in the middle west where it is but a very recent development. The last twenty years marks the extension and expansion of our engineering schools from feeble affairs graduating five or ten men a year, to powerful institutions each turning out annually hundreds of trained students; into colleges whose bulletins are eagerly sought by the great industrial interests of the country, whose experiments are watched by managers and superintendents far and wide, and whose laboratories furnish tests of interest to all the world. Most of this growth has in fact occurred within the last decade. Such rapid advancement can not help but to have taken place at the expense of thorough internal fusion and amalgamation. Things are, therefore, not yet quite settled. Plainly the evolution heretofore has been largely quantitative rather than qualitative. The future will witness the completion of the latter.

Everyone must recognize that there are many good points patent in the system as it stands. It can not be denied that the technical graduate has received a very good general education. He has had some history, perhaps a foreign language, mathematics, most sciences, in fact all the essentials and some little mechanical and specialized training besides. He stands equipped for good citizenship regardless of the line he elects as his life's work. Having had a trial or sample of nearly all fields of knowledge he is well qualified to select that for which he is best fitted, and he can afford to

specialize knowing he will not have to neglect any of the needful prerequisites. In addition to the fact that the courses are well rounded we find that they are more or less crowded so that, from the great amount of work covered in so short a time, the student gradually comes to realize the value of haste combined with precision. The mere practise in doing different things will itself be found valuable without regard to what is to be learned. So when he has finished his Senior year we must admit, I think, that our student is prepared in a fashion for outer world standards.

But we are only passively interested in the virtues of the present day order. The defects, since our attention is directed to their correction, must interest us more. First, let us consider the immense amount of work that must be done in the prescribed time. One might contend that the amount is not so vast as is indicated, were the student to attend strictly to his school-room affairs, but it must be acknowledged that a university community affords other advantages so various and diverse and so important that the contingency of their use must be considered a probability and due allowance made therefor. Such a rush of work soon puts a premium on dishonesty, and tempts the student to cheat. If he does not cheat, he must hurry everything so that the best he can do is never evidenced. His standard is lowered contrary to all the established ideals of education. He becomes so engrossed with the commonplace duties of everyday that he is inclined to become pragmatical; there is a tendency for him to become a mere automaton unable to step from beneath the onus of his calculations and see ahead to the final result. He loses all connection with anything but this little circle in which he moves, and the great outside world means as little to him as Hyperion, the seventh satellite of Saturn, does to any ordinary citizen. He even lacks the time to apply what he has learned in one course to his other studies; his accuracy outside a class in pure mathematics is doubtful, his experiments are not written up rhetorically or grammatically, and his sketches, outside the drafting room are hasty and crude. In fact, his general viewpoint is lost, and things, through some cerebrial myopia, do not exist in their proper proportion for him. Of course these things may not be prescribed in the curriculum for graduation, but nevertheless they are assuredly *sine qua non*.

The foregoing deficiencies are in consequence of the existence of too much work to be conveniently handled by the average student. Let us now investigate the effects of a prepondency of elementary work with a consequent disregard for more vital subjects, a condition which frequently, nay nearly always, obtains. By elementary work should be understood the fundamentals that ought to be covered outside the technical school. Such a situation is fatal to the development of that executive ability without which an engineer stands so little a chance for success. Also, it does not admit of much adapt-

ability being learned. The simple work is done by a simple method of "follow your nose and you'll get there," and the student does not shift for himself and can not learn to suit himself to varying conditions. He has nothing to bring forth and drill his powers of initiative. Besides being negatively detrimental, such a crowding of the curriculum with primary studies eliminates the possibility of much specialization. These evils are all quite serious.

There is another error. The connection between theory and practice, a bond that should be unseverable, is not maintained so intimately as is to be desired. Laboratory work may be given to supplement this teaching in the lecture room, but they are not securely interlocked, sufficient stress is not placed on the necessity of intertwining the one with the other.

These defects are not by any means permanent, however. A new era has dawned for our technical schools. After the late mushroom growth things are settling to a position of true equilibrium. The palpable lack of capable instructors and even of text books is being eradicated. Gradually yet visibly, year after year, standards are being raised and courses are being amplified and added, and improvement spread in every direction until one can easily imagine a time when what is now the graduate school will be the university proper. Engineering education in apogee!

THE ELECTRICAL ENGINEERS' SHOW.

B. M. Beach, E. E., '09.

The Electrical Show, given by the students in Electrical Engineering in the University this year, was a success from every point of view. The number of visitors, the quality and scope of the exhibits, and the handling of the work by the men in charge, were very gratifying to the management and to the faculty of the department.

The Show as an institution was started a year ago, when the first exhibition of the kind ever given at Illinois was held about the first of March. Two evening and one matinee exhibitions were given. This year no afternoon shows were given, partly because of the light attendance at last year's matinee, and partly because the rather elaborate lighting and decorative effects which have become so important a feature of the Show would lose their attractiveness in the day-time. Three evenings were found necessary for the accommodation of the large number of visitors. The dates this year were Thursday, Friday, and Saturday, April twenty-sixth, twenty-seventh, and twenty-eighth.

The purpose of the Show is two-fold; to give residents in the Twin Cities and the surrounding country, and students in the University, an opportunity to see the recent advances in the application of electricity to the needs of the human race, and to give the students in the department a practical "workout" in installing and handling electrical machinery and appliances under conditions approximating those of commercial practice. Both objects were achieved to a flattering degree. The wireless telegraph, high frequency demonstration, telegraphone, 100,000 volt transformer, singing arc, Poulssen arc, and the static machines and other apparatus exhibited by the Physics Department were exhibits that drew appreciative attention from all the various classes of visitors, while those well versed in matters of science found them of real value. Features of a more popular nature were provided for entertainment, among them being the electrical cooking exhibit conducted by the Woman's League of the University with the apparatus loaned by the Commonwealth Edison Company of Chicago, the miniature railway, the electric telescope, the electric incubators with chickens hatched by electricity, the "Freak Room," the electric fountain, the demonstration of the Bell and the Automatic telephones, the military telegraph as used by the Signal Corps, the Shadowgraph, the electrical museum, and the plant growth by electricity. A "perpetual motion" (?) machine was discovered (?) in time to be placed on exhibit, and attracted a good deal of attention.

The experience gained by the students was undoubtedly of great practical value. For a week before the Show from forty to

sixty men were at work daily, and sometimes the number included almost the entire enrollment of the department. These men were given the best possible opportunity to benefit by the work assigned them, because in each case they were told what was needed and they simply took the job into their own hands. Many underclassmen received their first experience in wiring circuits and handling electric machinery, while the older students were given excellent training in handling men, and learned some very valuable lessons in economy of materials. The time put in on the Show was in nearly all cases in addition to the regular school work, as very little interference with classes was desired or permitted. To many students this meant no little sacrifice of time and effort, but the cheerfulness with which help was offered shows that the men appreciate the significance of the Show and the value of the experience gained by sharing the work and responsibility.

Perhaps next in importance to the actual experience of taking part in the preparations for the exhibition is the fellowship and loyalty developed as a direct result of the contact of all the men in the department while working toward the same end. Personal feeling was eliminated to a remarkable degree, and all seemed to realize that only by faithful devotion to the cause, could satisfactory results be obtained. In the necessarily hasty and incomplete organization of the working force there was often conflict of authority and petty annoyance that might well have caused serious trouble had the men not placed the "good of the service" above everything else and cheerfully attacked problems from the standpoint of how-can-I-get-this-done rather than how-soon-can-I-go-home. In all the engineering courses the students in different years are kept pretty well segregated from each other, so that sophomores and freshmen, juniors and seniors have little chance to make acquaintances in other classes than their own. For this reason the Electrical Show has an especial value to the department, as the men work side by side with representatives of other classes, perhaps differing widely from themselves in point of seniority. The experience of the last two years has clearly shown that the Show has drawn the Electrical Engineers together and developed pride in the department and loyalty to each other to a degree which no other student enterprise has approached.

In the actual conduct of the Show as well as during the period of preparation, it was merit and experience that counted, as against influence and seniority. It was not always the senior who was put in charge of a squad of men or who was asked to work out the details of an exhibit. Several of the executive positions were ably filled by men attending the University for the first time this year, while students of all classes were called upon to develop exhibits and take charge of construction work. Where underclassmen were given authority over older students, there seemed to be no resentment on the part of the older men, who evidently realized that the manage-

ment desired only to further the interests of the Show in the best possible manner.

The proceeds are to be used in some way which will benefit the students in Electrical Engineering. The reading room in the Electrical Laboratory, which has already been furnished by the Society, will be made more comfortable and convenient for those who go there to read the technical papers or to write. The exact manner in which the remainder of the fund will be spent is still undecided, but as the Show represents the whole department, the expenditure of its profits will be for the good of all E. E.'s.

The Electrical Show was advertised more extensively than are most enterprises conducted by students. Display advertising in the daily papers and The Illini was supplemented by news-stories of the progress of the work and the plan of the Show. Street banners were used to attract attention, while the lighting of the Library tower by means of arc lamps and the operation of search-lights from the top of University Hall helped arouse interest. The Electrograph, a four-page paper complete in one number, and devoted to the description of the exhibits and explanations of the purpose and scope of the Show, was published just before the opening of the exhibition, and copies were sent to the nearby towns. Men were sent out along the Interurban both east and west, carrying advertising matter and tickets.

In view of the great amount of temporary wiring installed for the Show, extra precautions were taken to avoid improper connections and prevent the outbreak of fires. The members of the faculty personally inspected every circuit, and a rule to the effect that no circuit was to be used until approved was strictly enforced. Temporary fire-escapes were placed on the building, and extinguishers were placed at convenient points. Part of the lighting of each room was supplied by the storage battery, so that a failure of the city current from the power plant would not thrown the whole exhibition in darkness.

The organization in charge of the Show was comprised of F. L. Cook, general manager; G. E. Jaquet, installing engineer; and B. M. Beach, treasurer. L. E. Pease was in charge of construction and inside lighting, and F. L. Hanson was assistant engineer. The seniors were in charge of exhibits or held executive positions, and the same is true to less extent of the juniors, while the underclassmen helped where most needed.

THE ELECTRICAL ENGINEERS' TRIP.

K. E. Hellstrom, E. E., '08.

The annual inspection trip taken by the Senior Electrical and Railway Engineers this year was probably the most extensive, as well as the most interesting ever attempted. The party consisted of thirty-three students in the care of Professor Morgan Brooks, head of the Electrical Department of the University, and E. I. Wenger, of the Railway Department, the trip covering a period of two weeks, from November 3rd to the 16th. The program follows:

Sunday, November 3, 2:40 p. m.—Left Champaign via C. C. C. & St. L. for Niagara Falls.

Monday, November 4, 8:00 a. m., Eastern Time.—Arrived at Niagara Falls. Ontario Power Company; Electrical Development Company; Gorge Route. Headquarters in Niagara Falls, Imperial Hotel.

Tuesday, November 5.—Niagara Falls Power Company; Carborundum Works; National Pure Food Company. 7:20 p. m. left Niagara Falls via West Shore R. R. for Schenectady.

Wednesday, November 6.—General Electric Works. 5:00 p. m. left Schenectady for Albany. 8:00 p. m. left Albany via. People's Line S. S. Co. boat for New York.

Thursday, November 7—New York Headquarters, Grand Union Hotel.—Interborough Rapid Transit Company's Power Plants and Subway Lines; Interborough Company's Tunnel under East River to Brooklyn; New York Central; Telephone Exchange.

Friday, November 8.—New York Edison Company's Power Plant; New York Central R. R. Electrification D. C. System; New York, New Haven and Hartford R. R. A. C. Electrification. 8:15 p. m. American Institute of Electrical Engineers' Meeting.

Saturday, November 9—Edison Lamp Works, Harriston, New Jersey; 3:15 p. m.—Left New York via Old Dominian S. S. Co., boat for Norfolk.

Sunday, November 10, 9:30 a. m.—Arrived Norfolk. Headquarters Colonial Hotel.

Monday, November 11.—Jamestown Exposition; 6:00 p. m., left Norfolk by boat for Washington.

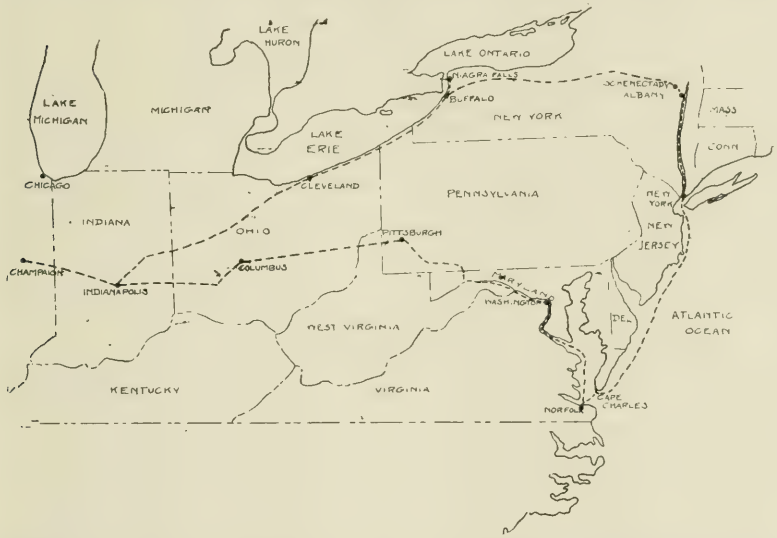
Tuesday, November 12, 7:00 a. m.—Arrived Washington, Headquarters Dewey Hotel. Treasury; Washington Monument; Bureau of Engraving and Printing; Smithsonian Institution; 12:30 p. m., White House; Capitol; Navy Yard; Library of Congress.

Wednesday, November 13—National Bureau of Standards; 1:22 p. m., left Washington via Baltimore & Ohio R. R. for Pittsburg; 9:42 p. m., Arrive Pittsburg.

Thursday, November 14—Westinghouse Electric and Manufacturing Company; Westinghouse Machine Company.

Friday, November 15.—United States Steel Company's Homestead Works; Bessemer Steel Company's Works; 9:10 p. m. Eastern Time. Left Pittsburg via Baltimore & Ohio R. R. for Champaign.

Time was rather limited throughout the entire trip, and, in order to facilitate travel, and keep the party together, six leaders were elected by the class and each leader was responsible for the men in his group. This arrangement also assisted materially in the inspection, as a guide was usually assigned to each group, and the men



could thereby get in closer touch with the details of operation and points of particular interest in the various plants to which they were admitted. From the time the special car left Champaign with a large banner bearing the inscription "University of Illinois Electrical Engineers," until the return, everybody was anxious to see and learn all about everything, and nobody was in the least disappointed.

The extensive power plants at Niagara Falls, both on the American and Canadian sides, were highly instructive from a practical standpoint, giving the students a chance to see the largest and most up-to-date plants for the development of water power in the world. After going through the National Pure Food Company's establishment the men were invited to lunch on the finished product, and the fact that there were no refusals indicates the great care exercised in preparing the modern cereal breakfast food. The visit to the Car-

borundrum works was a rare opportunity to see the practical operation of the electric furnace, and its direct application to modern industry. Aside from the practical operating knowledge of power plants the visit to Niagara afforded to several the opportunity of seeing for the first time what is probably America's grandest natural beauty spot.

The visit to the General Electric Manufacturing Company's plant at Schenectady took the party through some three hundred buildings, devoted exclusively to the manufacture of electrical appliances. The students were able to see the practical result of the company's welfare work among its employees, and its success, as attested by the appreciative attitude of the workers. The party lunched with the employees in the company's dining rooms, and had every opportunity of seeing for themselves the conditions governing the apprenticeship courses in the modern electrical manufacturing concern.

A considerable time was spent in New York City, and it was the busiest part of the whole jaunt. The power plants of the Interborough and Edison companies are excellent examples of what a large, up-to-date, and well managed concern should be; and the operation of the Subway, which so readily solved the downtown traffic problem of the great metropolis, was very instructive. Another interesting engineering project visited, was the Interborough Company's tunnel under the East River to Brooklyn, which was nearing completion. The party was permitted to walk through its entire length, about 6600 feet, and see the process of construction, the main features of which were the reinforcement and ventilation. The New York Central Telephone Exchange also afforded an excellent opportunity for the men to understand something of the huge problem which must be worked out by the telephone engineer. The electrification of two of New York City's largest steam roads, showed the practicibility of this idea, which has been a subject of much recent discussion and the thorough demonstration by expert operators of the running of through cars, was of more than ordinary interest. A visit to the Edison Lamp Works at Harriston, N. J., was interesting in that it showed every detail in the complicated manufacture of the much used carbon filament lamp, and it also demonstrated that women can be employed to decided advantage in modern industry for the employees of this company, like the Telephone Exchange, consisted almost entirely of the weaker sex. All of the time was not spent in search of technical knowledge, however, for the New York Alumni Association entertained nicely at a banquet, and the evening was devoted to the renewals of many old friendships formed at Illinois.

The party was very fortunate in being in New York City on the evening of the regular meeting of the American Institute of Electrical Engineers, and the paper on the "Comparative Perform-

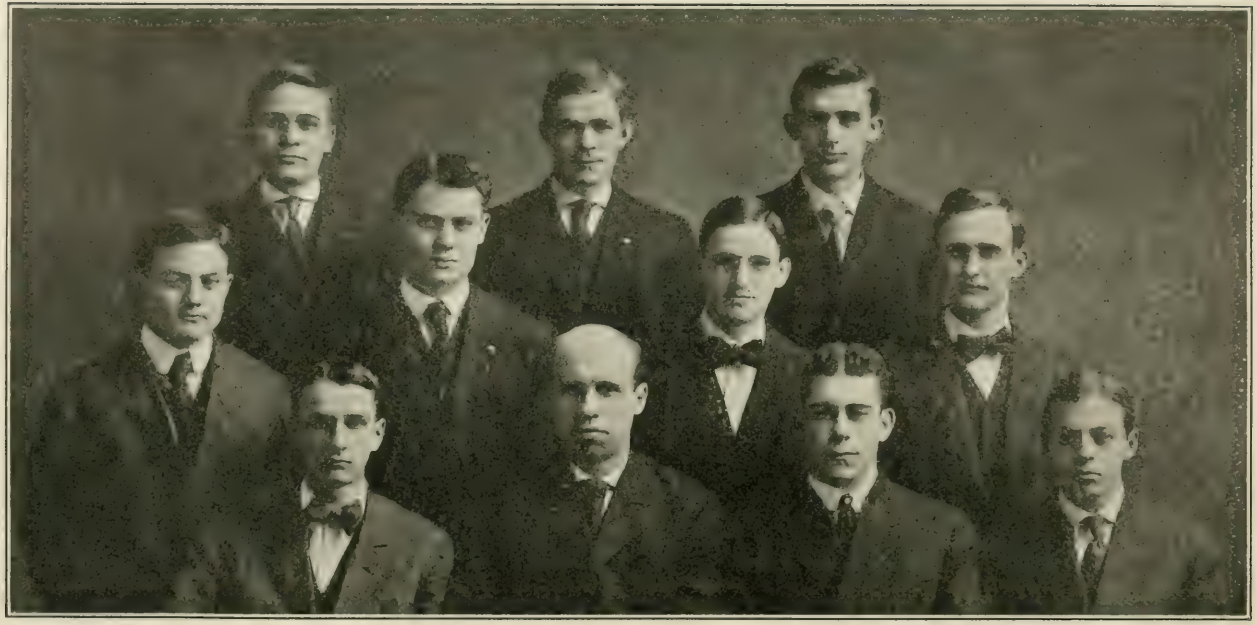
ance of Steam and Electric Locomotives," brought out some excellent discussion from several leading engineers. This gave the men a good idea of the nature and purpose of the Institute meetings, in which, as student members, they are directly interested, and also gave them an opportunity of meeting influential men of the engineering profession. The visit of Dr. Chas. P. Steinmetz was undoubtedly a direct result of the attendance at this meeting.

The trip to Norfolk by water was pleasant enough, and two days were spent in sight-seeing at the Jamestown Exposition, which did not leave a very favorable impression, although some of the exhibits were decidedly instructive. Washington furnished an excellent stamping ground and Uncle Sam as an engineer was quite up to expectations. The Washington Monument, Treasury, Bureau of Engraving and Printing, and the Smithsonian Institution, were very interesting. The beautiful Capitol and Library of Congress also impressed the men with their magnificence, and a very good insight into the lives of the nation's employees was obtained by seeing them at their work. Half a day was spent in going through the National Bureau of Standards, and many were surprised at the exactness of the work done there, as well as the ingenious means devised for doing it. The men seemed totally wrapped up in their work, and were not at all loath to explain and demonstrate the details and construction of the apparatus which they employed, and the results which they desired. The party was again exceedingly fortunate in being admitted to the presence of he nation's chief executive, and most of the men will not soon forget the privilege accorded them of shaking his hand.

Pittsburg was the last stop, but there was so much to see and absorb that nobody had time to think of being tired. A visit to the Westinghouse Company's Works gave the men a chance to compare this company with its competitor, the General Electric, in regard to chances and desirability of future employment, especially in the apprentice courses, where they would probably qualify. A fair opportunity was also given to compare the management, equipment, and engineering merits, of the two concerns. The application of electric power to the handling of material in the immense steel mills of the United States and Bessemer Companies, was a study in itself of the rapid growth of the electric motor for all kinds of power purposes. It was a notable fact that the metal was not handled at all by man power from the time it entered the huge furnaces until it was cast from the last machine in the required form. The machines were ingenious indeed, and to say that the operators were experts is putting it mildly.

Probably the greater good derived from the trip, and the one which alone would have made it worth two weeks of class-room work and the money expended, was the direct contact with the electrical engineering world. Many men fail because they go out to

work without any definite idea of what practical engineering really means, and they start wrong, get discouraged, and quit, because they think they are not appreciated. The men were given opportunity to see what each special branch of their future profession would require of them, and they were thereby helped in choosing their respective lines of work. They were spurred on in their efforts to get everything possible in their class-room work in order that they might be better able to cope with the problems which they saw confronting engineers everywhere. They met many influential engineers, who will be pleased to remember them if the opportunity offers, and that alone is a good asset when scouting a job. They met many old college friends, whom they were glad to see; men who had completed their college work, and were making good in the world, and they longed to be with them and push.



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EDITORIALS.

On February 5, 1908, Doctor W. F. M. Goss was formally installed as Dean of the College of Engineering. Prof. White, who had acted as Dean during a two years' interum, was in the chair, and was given many tributes for the splendid way in which he had handled his responsibility. The ceremonies, which were impressive, were concluded by the presentation of a magnificently bound volume, a gift from the faculty, to Prof. N. C. Ricker, whose resignation from the head of the department caused Doctor Goss' arrival.

Dean Goss arrived here on October 31, 1907 to take charge of the School of Railway Engineering. He has had extensive practice in his profession, both in Europe and America, and, while in charge of the Department at Purdue University, established an enviable reputation for it. The University community, students as well as faculty, consider his acceptance of the Deanship as a great gain to the College.

This number of the Technograph has been dedicated to Dean Goss, not only for the above reasons, but because, from the first, he has shown great interest in its publication. The opening article in the number was written by him, and should prove of interest to everyone who has studied railway conditions on the Continent.

In arranging the material for this issue, the attempt has been made to keep like subjects together. Besides the article by Dean Goss, mentioned previously, G. E. Jaquet, of the R. E. E. Dept., has furnished a paper which calls forth our acknowledgement on account of the amount of time expended on its preparation, and the excellence of its subject matter. In passing, we wish also to make mention of the paper by A. Brundage, which presents the undergraduate's side of a knotty question to advantage.

During the year we have received a large number of bulletins from the Forestry Service, and, in acknowledgement, they have been abstracted by R. C. Wagner, of the board. The information should be of interest to anyone who has to do with timber.

We wish also to acknowledge the receipt of the Cornell Civil Engineer, and of bulletins from Wisconsin University, and from Colorado School of Mines.

We regret that, owing to the large number of changes necessary to make it suitable for our purpose, we were unable to present Mr. Abram's report of work done in the Experiment Station during the past year, and that, for lack of space, it was impossible to publish a report of the lecture given here last fall by Doc. Steinmetz.

With the election of the new Technograph board members, the Engineering Annual will start on its twenty-second year. It is certain that in such a period the worth or uselessness of such a periodical should have been demonstrated, and, if worthy, some chance to make a radical improvement should be given it. All the stories that the underclassmen are told to the contrary notwithstanding; the faculty, the students, and most of all, the board, know that the Technograph is appreciated. We will not enumerate proofs—the fact that a Wisconsin University professor recently remarked that he used the Technograph for a textbook shows its value.

While we regard the change of the Technograph to a quarterly as an immense improvement, the fact may have to be proved to many who believe such a step would be unwise. In recommending such a change to the Engineering Societies, and urging their immediate and conscientious action, we do so without the slightest fear that the standing of the Technograph will be injured by such a change. We do not advise a quarterly filled with class room notes and other such material, valueless to the outside engineer—such a change would be suicide. But the act of increasing the issue, at the same time maintaining our present standard, would merely show our readers that we possess the requisite material to fill such an issue.

As to the financial question. Needless to say, some new plan would have to be adopted between the clubs and the board to insure support. The advertising, which in a publication like ours forms the main resource, would be easier to obtain, but, at the same time, the issues would probably cost about as much as at present, since it is not the suggestion of the board to make each quarter's issue much smaller than the present annual. Possibly the present system could be continued, giving the members of the club two issues, and trusting to their desire for completeness to buy the other one.

Scarcity of material has not proved a drawback to the past management, and should not if the issue were changed, indeed, the financial state of the journal would, then as now, control its size. It is certain that a quarterly would assure an outside subscription list of some size, and that such a list would, in its turn, assure a reception of communications and articles. In case the matter is taken up, we earnestly urge upon every member of the '08 class to support the movement in this manner. The fact that the work of publication would be spread over an entire year would make the amount of available University material greater.

In the matter of exchanges, we wish to remind the clubs that at present we exchange with several semi-annuals, and that it

would be entirely possible, if necessary, to arrange to continue this feature in some way.

The above discussion about covers the actual *difficulties.* When the matter is brought up before the clubs, other points, such as the fairness of expecting a management to put in three times as much work as at present with no return; the necessity of the election of competent and energetic men to the board; and various financial details not mentioned herein; can be brought up and decided.

And now, in closing, we wish to urge the Societies to give this project all possible favor in their consideration, from the very fact that Cornell, Wisconsin, Minnesota, Boston Tech, Armour Institute, and many other schools, are making a success of such issues, while we; who have no superiors among those schools, are content with an annual. Do not have it said, without careful consideration on your part, that we have not enough energy and material to support a publication fully worthy of our standing among the Engineering Colleges of the United States.

MECHANICAL ENGINEERING SOCIETY.

The Mechanical Engineering Society has a twofold aim: To get men of note in the engineering profession, either in investigation or educational work, or in commercial practice, to speak before the Society and thus put us in touch with the subjects that are interesting engineers all over the country; and to bring them together in some activity outside the class room and yet belonging distinctively to them, to improve their esprit de corps,—to "put them next" to each other. A brief summary of our work during the current year will serve to show how well we have carried out this purpose.

Addresses were given as follows: Prof. L. P. Breckenridge, head of the Mechanical Engineering Department, "Mechanical Engineering;" Mr. G. M Brill, M. W. S. E., Consulting Engineer, "The Average Power-Plant;" Mr. R. D. Tomlinson, Steam Engineer of the Allis-Chalmers Co., "Condensers and Their Application;" Mr. S. R. Lewis, Jr., of Lewis & Kitchen, "Modern Heating;" Mr. W. H. Vandervoort, of the Moline Automobile Co., "Automobile Engines;" Prof. J. C. Thorpe, Assistant Professor of Mechanical Engineering, "Recent Steam Turbine Developments;" Prof. Breckenridge, "The Evolution of the Atlantic Liner;" Prof. Benjamin, Dean of the College of Engineering of Purdue University, "The Evolution of the Machine Tool;" Mr. H. B. Dirks, Instructor in Mechanical Engineering, "Superheated Steam." Informal five minute talks by: C. S. Pillsbury, '07, on a summer's work in an Arizona copper-mine; R. E. Robinson, '08, on the inspection service of the A. T. & S.-F. R'y; F. Van Inwegen, '08, on power-plant design.

Arrangements have been made for an address by Dean Goss on modern German engine practice; and in order to get talks from the students the Society has issued a call for bids on the equipment of an imaginary power-plant. These bids are to be submitted by the members of the Society as representatives of the companies making the different apparatus, for the consideration of a board of directors, and it is expected in this way to give an insight into the methods of buying and selling engineering equipment.

As to the social side of the work, in the two or three meetings where refreshments were served and at the smoker which was given in the fall we at least kept up, while at the second smoker to be given in the spring we expect to add, to the M. E. reputation for being a "live bunch."

C. E. CLUB.

On May 9th, 1907, the C. E. Club met in Adelphic Hall for the last reception of a most successful year under Pres. Kinsie's leadership. At the conclusion of an enjoyable evening, the following officers were elected for the next semester: President, A. N. Heaney, '08; Vice President, C. M. Slaymaker, '08; Secretary, E. B. Adams, '08; Treasurer, K. H. Talbot, '09; Sergeant-at-Arms, A. M. Korsmo, '09.

During the first semester the Club was addressed by Profs. Brooks and Dufour, who spoke in the opening meeting; Prof. Baker, on "Bridge Accidents;" Prof. Bleininger on "Manufacture of Portland Cement;" E. H. Ackerman on "Buffalo Track Elevation;" G. E. Tibbetts and F. L. Stone on "Chicago Track Elevation." At the close of the semester C. M. Slaymaker, '08, was elected as President; A. M. Korsmo, '09, as Vice President; W. H. Raynor, '09, as Secretary; R. C. Wagner, '09, as Treasurer, and I. J. Shields, '10, as Sergeant-at-Arms.

The annual C. E. Smoker was held at K. of P. Hall on March 14, 1908, under the direction of Arthur Schwerin, chairman of the committee. About two hundred attended, and were shown an enjoyable time. Dean Goss and Profs. Baker, Brooks, Dufour, Bayley and Bleininger helped to make the event a success.

The Senior trip, from April 14 to April 19, was to Chicago, as usual, the plans for a Pittsburg trip being regarded as unwise. The usual complete inspection was made. Besides, during the first semester, trips were made to Mahomet and Mattoon, Ill., to inspect bridge, and water supply work respectively.

THE ARCHITECTURAL CLUB.

NEW OFFICERS. At a recent meeting of the Club, held early in March, the new officers for the second semester were elected. Mr. W. H. Beyrer, a Junior, was chosen for President. It was in pursuance of a long established custom of the Club that the office of President for the second semester was given to a Junior. The President for the first semester is always chosen from among the Seniors. The other officers elected were: Fritz Wagner, Vice President; Ramon Schumacher, Treasurer; J. R. Fugard, Secretary.

CONVENTION. The Architectural League of America, of which the Achitectural Club is a member, will hold its annual convention at Detroit on the 17, 18, and 19th of September, next. The fact that the dates set are so near the time of opening of school in the fall will make it difficult for any of the club members to attend the convention. There is a movement on foot among the Senior members to arrange for a reunion at Detroit at the time of the convention. The Club was for a number of years the only student organization represented in the League.

MEMBERSHIP. The membership of the Club for the present year has been about 70. This number comprises about three-fifths of the students enrolled in the department.

SCHOLARSHIPS. Harvard University announces three scholarships open to all members of the Clubs included in the League. One of the scholarships is to be awarded to the applicant who passes with the highest grades the entrance examinations at Harvard; the other two scholarships are to be awarded to the winners of first and second place in a competition in design only. Each of the scholarships consist of a year's tuition ($150) in the School of Architecture at Harvard.

The Architectural League also offers a traveling scholarship, open to its own members, of one thousand dollars a year for two years, it being required that the time be spent in foreign travel under the direction of the League.

BANQUET. Plans for the second annual banquet of the Architectural Club are now under consideration. The date and details have not yet been announced. The first annual banquet was held in March last year at the Beardsley Hotel. Fifty members attended then, and it is hoped that even more will attend this Spring.

ANNUAL. "The Architectural Annual," published by the League in February, contained about twenty pages devoted to the work of members of the Club, past and present. About ten pages were given to illustrations of drawings.

RETAINING MEMBERSHIP. Through a change in the Constitution of the Club, effective last year, it is now possible for any member, of two years' standing, to still retain his membership upon leaving the University by merely paying the regular dues of the Club. This enables members who cannot locate near Chapters of the League to retain the benefits of membership in the League.

LECTURES. The Club enjoyed several lectures last semester and has several in prospect for this semester.

TAU BETA PI.

Last fall the initiates into the Illinois Alpha Chapter of Tau Beta Pi, the honorary engineering fraternity, were: H. C. Dean, E. E. '09; H. A. Brand, A. E. '08; S. E. Campbell, C. E. '08; M. R. Haynes, C. E. '08; F. N. Ropp, C. E. '08; F. L. Hanson, E. E. '08; K. E. Hellstrom, E. E. '08; G. E. Jaquet, R. E. E. '08; R. E. Robinson, M. E. '08. This spring the new members were: W. H. Beyrer, Arch., H. D. Oberdorfer, A. E., H. Burgess, C. E., A. Brundage, C. E., W. C. Johnson, C. E., W. T. McClenahan, C. E., C. E. Ramser, C. E., H. H. Simmons, C. E., B. Van de Greyn, C. E., H. E. Ercanbrack, E. E., H. S. Lofquist, E. E., R. Schumacher, E. E., P. M. Burke, M. E., C. A. Herrmann, M. E., C. T. Ripley, R. E. E., all from the class of 1909.

THE TECHNOGRAPH

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Associated Engineering Societies

COMPRISING

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OF THE

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VOLUME XXIII

UNIVERSITY OF ILLINOIS
CHAMPAIGN OR URBANA
1909

TO LESTER PAIGE BRECKENRIDGE,

WHOSE PRESENCE AND INFLUENCE HAVE BEEN MOST HELPFUL

TO EVERY ENGINEER IN THE UNIVERSITY,

THIS VOLUME OF THE TECHNOGRAPH

IS RESPECTFULLY DEDICATED.

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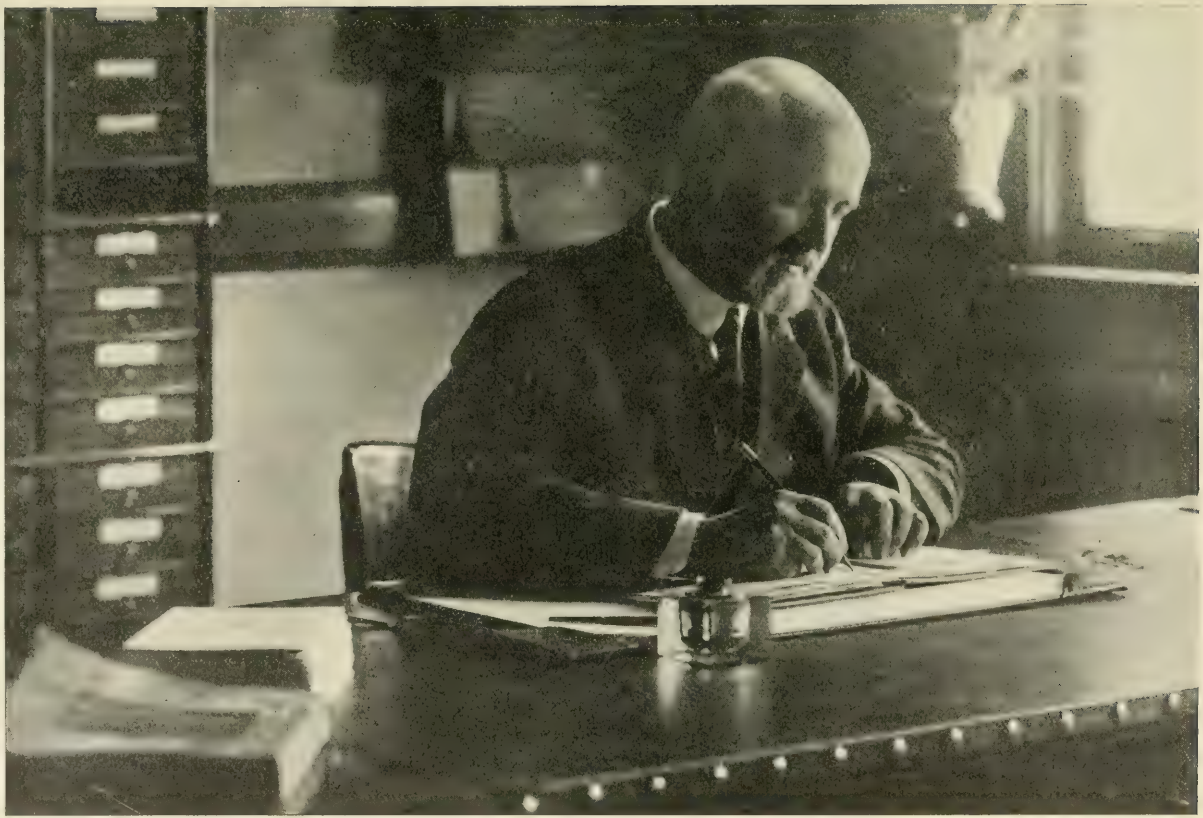


LESTER PAIGE BRECKENRIDGE

THE TECHNOGRAPH

No. 23 UNIVERSITY OF ILLINOIS 1908-1909

LESTER PAIGE BRECKENRIDGE.

The announcement made and confirmed in February, to the effect that at the close of the present college year, Professor Breckenridge would give up his work at the University of Illinois, has been received on every hand with expressions of sincere regret. Among those to whom his going will be regarded as a distinct personal loss, are many readers of THE TECHNOGRAPH. It is fitting, therefore, that the present issue contain some formal statement of the work he has accomplished and some recognition, however weakly framed, of those qualities of his character which have so endeared him to his friends. It is but just also that there be added some explanation of the considerations which have influenced his action.

Lester Paige Breckenridge was born at Meriden, Connecticut, in 1859. He graduated from the Sheffield Scientific School of Yale University with the Class of 1881, and devoted a number of years to practical engineering work in various parts of New England. Following this, he spent eight years as a member of the instructional staff of Lehigh University, where, as assistant to Dr. J. F. Klein, he helped to build up a strong department of mechanical engineering. From there he went to Michigan Agricultural College at Lansing as Professor of Mechanical Engineering. He resigned his professorship at Lansing to accept a similar position at the University of Illinois in 1893, which position he now proposes to relinquish.

The sixteen years that have passed since 1893 represent a period of remarkable development in the College of Engineering of the University of Illinois, in which development Professor Breckenridge has had an active part. The present shop laboratories, the boiler house with its system of tunnels extending to every part of the campus, and the mechanical engineering laboratory with its elaborate equipment of machinery, are all monuments to his genius

and skill. It was in response to his suggestions that the Engineering Experiment Station, the first of its kind in connection with a state institution,was organized, and its work has since proceeded in obedience to his wise direction. While never for a moment forgetting the needs of the College of Engineering, his influence has been extended broadly throughout the University and the state. His attitude toward all matters of common interest was well described by President A. S. Draper some ten or twelve years ago, who responding to an inquiry concerning Professor Breckenridge, said, "Oh, Breckenridge is the man over at Illinois who makes the wheels go round."

Few members of the instructional staff are known by so many students. Wherever the Illinois men have met to smoke or feast, he, more than any other, has cheered the board. In matters involving the special interests of students, there has never been doubt as to where he stood; his yea has been yea, and his nay, nay. He was the first to be elected an honorary member of Tau Beta Pi, and has recently served a year as President of its Council. Graduates delight to meet him, and delegations of visitors have been charmed by the enthusiasm with which he has shown them about the University. As a member of the University Senate and of various committees, he has had his part in ordering the general interests of the University. He was an effective promoter of the University Club, and is now its President. In his work as an expert in the broader field of engineering practice, he has acted for the Chicago Edison Company in making tests of its epoch-making installation of steam turbines, and for the United States Geological Survey in directing the work of fuel testing at the Louisiana Purchase Exposition. His researches, based upon the work of his own laboratory, concerning the conditions to be observed in burning Illinois coal without smoke, have served greatly to extend his reputation. He is now a Vice-President of the American Society of Mechanical Engineers.

This statement, although brief, will suffice to indicate with what degree of fullness Professor Breckenridge's service has been rendered. It is easy to understand why it is that students, alumni, and professors alike regret his going. If they find difficulty in explaining it they must remember that Professor Breckenridge was born and bred in New England, that his relatives are there still, and that his friends are as numerous there as here. These and an inborn love for the hills of the land of his nativity, are to one of his

temperament, influences of no small moment. As an alumnus of the Sheffield Scientific School, he is greatly interested in the welfare of that institution, and the fact that he has been invited to succeed Professor Richards, who having reached the retiring age, is content to give up the duties of his office, brings to him an opportunity which in a peculiar way challenges his ambition, and appeals to his loyalty toward his alma mater. It is not that Illinois lacks opportunities or inspiration for great work, or that the work at Yale will be more attractive, but it is the call of New England and of "Sheff." From a decision thus carefully reached and honestly sustained, there is obviously no appeal. The only response that can be given by his friends at Illinois must be characterized by the same generous spirit that Professor Breckenridge has always extended to all of his University associates. We can do no less than to accept his judgment, to rejoice with him in the fullness of his opportunity, and to wish for him the best that "Sheff" can give.

For ourselves, we have the satisfaction of knowing that Professor Breckenridge will continue at Illinois until September next. It goes without saying that in the interval, provisions will be made to cover every interest which will be affected by his going. We shall not find another Professor Breckenridge, for that will be impossible; but we shall belittle ourselves and discount the value of the complex and resourceful organization, which Professor Breckenridge has helped to build up, if we feel that the work of the college is to lose in effectiveness by such a change, or that any real interest will be permitted to go unprotected.

W. F. M. Goss,

March 24, 1909. Dean of the College of Engineering.

THE ILLINOIS ENGINEERING EXPERIMENT STATION.

L. P. BRECKENRIDGE, Ph. B.
Professor of Mechanical Engineering and Director of the Station.

The Engineering Experiment Station of the University of Illinois was established by action of the Board of Trustees, December 8, 1903, in connection with the College of Engineering.

There were two influences which led to its establishment; first, a demand from the industrial interests of the State for scientific experimentation relating to manufacturing process, fuel economies, and transportation problems; second, the very great success attending the work of the Agricultural Experiment Station at the University which made it evident that a similarly successful career ought to be possible for an engineering experiment station. It is very evident from the work which has now been accomplished by our Station and the many helpful things it has done for the industries of the state, that no mistake was made in establishing such a station.

ORGANIZATION. The control of the Engineering Experiment Station is vested in the heads (9) of the several departments of the College of Engineering. These constitute the Station Staff, and with the Director, determine the character of the investigations to be undertaken. The investigations are carried on by the members of the Staff directly, by fellows as graduate work, by members of the instructional force of the College, and by special investigators belonging to the Station corps.

PLAN AND SCOPE. It is the purpose of the Station to carry on investigations along various lines of engineering, and to make studies of problems of importance to professional engineers, and to the manufacturing, mining, railway, constructional and industrial interests of the State. It is believed that this experimental work will result in contributions of value to engineering science and to the industries of the state and that the pursuit of such investigations will give inspiration to students and add to the value of the instructional work in the College of Engineering.

REPORTS PUBLISHED. The results of the investigations made are published in the form of bulletins which record mostly the experiments of the Station's own staff of investigators. There are also issued, from time to time, circulars and compilations giving the results of the experiments of engineers, industrial works, technical institutions and governmental testing departments. The bulletins of the Station are distributed among the engineers and manufacturing interests of the state of Illinois, to libraries and the technical press of the country and to such special organizations as are practically interested in the subject matter discussed by individual

bulletins. Already there have been published thirty of these bulletins, and from five to twenty thousand copies of each one have been distributed.

All graduates of the College of Engineering are placed on the "all-bulletin" mailing list and undergraduates may secure the bulletins at the office of the Director. At present about one-half of the bulletins printed are sent to residents of Illinois, the other half are sent to residents of other states and foreign countries. That the work of the Station is fully appreciated by engineers, manufacturers and others is shown by the hundreds of congratulatory letters received by the Station as well as by the very considerable space given in the best technical papers to the reproduction of its papers and to favorable editorial comment. It is particularly desired that the bulletins of the Station should be received by all persons in Illinois interested in the numerous problems which connect its many industrial activities with the researches of engineering and applied science, such as manufacturing, mining, railway transportation; the chemistry and heat values of Illinois fuels; coal consumption in boiler furnaces, in gas producers, or in residence heating furnaces; the strength of materials used in building engineering structures; the strength of concrete both plain and reinforced; the durability of road material; the flow of water in pipes, conduits and channels; the sanitary problems of industrial corporations and municipalities; the generation, transmission and use of electricity; the problems of architectural construction, roof trusses, columns, base plates, piers and foundations; the cost of power and the problems of heating and ventilation; the problems of heat transmission, radiation and absorption; the problems of speech- and signal-transmission and many other problems which the above enumeration will suggest.

In the wise distribution of the publications of the Station, the engineering graduate may be most helpful and he should request that bulletins be sent to such persons as he knows would use and appreciate them. There are in Illinois about one hundred fifty public libraries and these all receive our bulletins. They should be urged to preserve their copies, as many of the earlier numbers are now out of print and are not easily procured. The demand for several of our bulletins was so much greater than anticipated that it was found necessary to print a second edition.

RELATION TO AND INFLUENCE UPON EDUCATIONAL WORK.. It was our thought at the outset that the pursuit of definite experimental work would give inspiration to our students and add to the value of the instructional work of the college of engineering. We have found this to be true. The work of the Station has had a marked effect in strengthening our instructional work. The contact with scientific experimentation and the methods of presenting the results in carefully prepared bulletins is a most helpful factor in the training of the young engineer. It is impossible for our

experimental work to go on without attracting the attention of our students. The work must be carefully and accurately done; the preparation of charts and diagrams and the checking and rechecking of results and computations involve extreme care and accuracy. The fact that students see how problems are taken up, how they are solved, and the whole work satisfactorily presented, is perhaps the greatest single educational gain to them. They live in an atmosphere of research which they unconsciously absorb. They realize that failure to contribute each particular assignment with accuracy may result in the failure of the entire experiment. While the investigations are carried on by the experts of the Station, there is abundant opportunity to make real use of student help in many tests and computations. The chance to participate in many of the tests is appreciated and eagerly sought by the students. They are interested in the direct application of theoretical principles to the solution of practical, everyday engineering problems. This illustrates the old pedagogical principle that when students are permitted to take part in real activities, they are more alert, interested and accurate than when merely carrying on exercise tests.

Some institutions have recently dropped the thesis requirement This appears to be an unfortunate move. It has probably been caused by large classes and insufficient help and facilities. In the work of this Station many subjects relating to researches in progress are capable of preliminary investigations as thesis work, and students pursue this work with unusual care and attention. Students are also greatly benefited by conferences with and lectures by our special investigators who are always in readiness to advise students along the line of their particular problems.

Encouragement and aid are freely given to members of the instructional force who desire to take up some line of research. In this way much excellent work is done which necessarily reacts on the quality of class instruction, and at the same time proves a source of development and broadening. This work serves to keep us all in close touch with outside engineering interests and practical everyday problems in the industrial world. While our bulletins record mostly the results of the Station's own staff of investigators, there is also the publication of circulars, giving compilations of the results of important experiments by engineers, industrial works, technical institutions and governmental testing departments. This opens up opportunities for our instructors who cannot undertake purely experimental work.

Each head of a department in the College of Engineering, being an active member of the Station Staff, is constantly on the alert to detect the possibilities of important lines of work and also to study the adaption of certain men to certain lines of work and to the possibility of developing investigators from our present body of students and instructional force. While it may be true that the

general investigator and experimenter, like the poet, is born and not made, still much may be done to develop the spirit of investigation. This in itself is always an element of true teaching and the awakening of a more general spirit of investigation would undoubtedly be an element of strength in all our educational work.

The facilities of the Station for research have made it possible to do real graduate work, and the action of the trustees in providing for ten research fellowships in the College of Engineering of an annual value of $500 will be a distinct gain to advanced engineering education. The rapid growth of the Graduate School of the University is also proving most helpful to the interests of the Engineering Experiment Station and an increasing number of scholarships and fellowships in this department is to be expected.

FACILITIES AND FUNDS. In carrying on the activities of the Engineering Experiment Station, there is necessary a large amount of equipment of various kinds suitable for investigational purposes. The regular equipment provided for instruction in the College of Engineering has largely been used for these investigations, supplemented by the purchase of special apparatus necessary for special researches in the Engineering Experiment Station. After an investigation has been concluded, the apparatus used becomes a part of the equipment of the department to which it most naturally belongs. The item of expense for equipment, therefore, does not enter into the general expenses of the Engineering Experiment Station. (The value of this total equipment in the College of Engineering is now, January, 1909, about $225,000.)

The funds expended in carrying on the investigations, already completed and now in progress, have been during the last five years a little over $150,000, making an annual expenditure of about $30,000.

The existence of the Engineering Experiment Station at the University makes it possible to utilize to great advantage

(1) The library facilities of the University

(2) The continual extension of the equipment of the various departments of the College of Engineering

(3) The helpful suggestions and direct cooperation of other scientific departments at the University outside of the College of Engineering.

With these three aids the expenditure of our funds is bound to result in much larger returns than would be possible otherwise.

During the first years of the Station's existence sufficient funds were available to carry on the work which the Staff deemed it wise to undertake, but during the last two years the funds have been entirely inadequate to carry forward with sufficient rapidity the work already started and many important lines of investigation demanded by several industrial interests of the State have been necessarily postponed. The Station is continually in receipt of requests

to furnish help on special problems of importance to our industries which it must refuse for lack of funds. When the industries really awake to the possible economies which may be expected as the result of the investigations of the Station, then much larger funds will undoubtedly be appropriated for conducting the work of the Station. There are as yet comparatively few persons who appreciate the position occupied by Illinois as an industrial center, and in the interests of the future needs of the Engineering Experiment Station, every effort should be made to advertise the facts which relate to Illinois industries. A few statements relating to this important matter are as follows:

(a) The population of Illinois is about 5,500,000 which is approximately 1-14 of the population of the United States.

(b) Illinois stands second in the value of its agricultural products, for 1908 the value being about....$550,000,000

(c) Illinois stands third in the value of its manufactured products, for 1908 the value being about..$1,600,000,000

(d) Illinois stands second in tons of coal produced, the value of this product for 1908 being about (51,000,000 tons) $54,000,000

(e) Illinois stands second in barrels of oil produced, the value of this product for 1908 being about (40,000,000 bbls) $24,800,000

(f) Illinois stands second in miles of railroad the number of miles in 1906 being about 12,000.

(g) The value of the mineral products of Illinois for 1908 which included coal and oil, was about.....$150,000,000 an increase of 65 per cent since 1905.

(h) The capital invested in the thirteen leading industries in Illinois is (1906).....$600,000,000
in the remaining industries 375,000,000

making a grand total of.....$975,000,000
This amount is now (1909) doubtless about $1,200,000,000

FUTURE WORK OF THE STATION. There are at present fully forty persons doing some work for the Station; of this number only thirty are devoting all of their time to the station work, the remainder giving a part of their time to its interests. There are now (March, 1909) in progress fifty-six different investigations which could doubtless be grouped under ten general heads. There are now fully one-hundred available investigations waiting for an opportunity to be started and for funds for carrying forward, such as a preliminary survey proves to be worthy. There will always be, for a station like Illinois, a continually increasing need of such investigations as are planned to be made by the Engineering Experiment Station. The Station is growing to be a *Public Service Research Laboratory* in the realm of applied science just as it was

originally intended it should be, and the results of its experiments will surely add to the wealth of the State, to the prosperity of the industries and to the health and comfort of its people. While this article can not give in detail the list of its experiments in progress and proposed, it may be well to indicate in a general way what are some of the problems which should evidently be given a prominent place in the future work. Such a list follows:

1. The determination of the strength of materials used in constructive engineering work. A very large and important field.
2. A study of municipal water supply and sewage disposal as affecting public health.
3. A study of the best methods of using economically the fuels of the state, not only for the production of power, but for the heating of buildings, metallurgical purposes, etc.
4. Use of Illinois coal in the gas-producer and gas engine.
5. Utilization of oil products for economical and industrial purposes.
6. Economic production and use of steam.
7. A study of the development, safety and economical use of the machinery and appliances used in mining operations.
8. A study of the development and economic production of manufactured products.
9. A study of the economic construction and maintenance of roads.
10. A study of the properties and strength of fabricated articles, such as bridges and frame work of important engineering machines and structures.
11. Generation, transmission and utilization of electrical energy.
12. A study and investigation of the economic and satisfactory methods of telephony.
13. A study of the problems of economic transportation of materials by rail and water. A very large field and rich in problems.

With such a program it is plain that the work of the Engineering Experiment Station can not end so long as the industries of the State are to progress and develop, so long as the fuel problems of the State continue to play such a prominent part in industrial and in domestic use, so long as transportation by steam, by electricity and by water continues to expand or so long as a knowledge of the strength of materials continues to play, as it always will, such a vital part in the construction of engineering works, the erection of state and private buildings, and the design and construction of all manner and kinds of manufactured products which our complex civilization now demands.

STABILITY OF MASONRY AGAINST OVERTURNING.

W. C. JOHNSON, C. E., '09.

In discussing the stability against overturning of retaining walls, dams, voussoirs of arches, foundation blocks, and similar bodies, most treatises on masonry construction are in error to some extent. There are two ways by which such stability may be determined: namely, algebraic and graphic. Algebraically, the factor of safety against overturning is the ratio $\frac{\text{RESISTING MOMENT}}{\text{OVERTURNING MOMENT}}$, $=$

$\frac{\text{MOMENT, ABOUT THAT EDGE OF BODY WHERE ROTATION MAY OCCUR, OF FORCES RESISTING OVERTURNING}}{\text{MOMENT, ABOUT SAME EDGE, OF FORCES TENDING TO CAUSE OVERTURNING.}}$

This factor, found in the other manner, is the ratio between two certain intercepts, upon the examined base of a section of the body, cut by graphically found resultants of all forces acting on the body. The graphic method is intended to yield the desired result, along with graphic solution of other features of problems, without the extra labor of the computations involved in the algebraic solution. Whether or not such labor saving may be effected in many cases, remains to be seen. As both methods are presented in standard works on the subject; only the graphic is questioned, the algebraic being so simple that it does not admit of question or of variety in treatment.

Attempting the graphic solution, some authors state, without qualification, that the factor of safety is to be expressed always as the ratio:

$\frac{\text{HALF WIDTH OF BASE OF SECTION UNDER EXAMINATION}}{\text{DISTANCE FROM MIDDLE OF BASE TO POINT WHERE RESULTANT OF ALL ACTING FORCES CUTS BASE:}}$

i. e., $\frac{\frac{1}{2}b}{c}$ in Figs. 1 and 2. This is true under certain conditions only, these conditions being THAT THE BODY BE SYMMETRICAL ABOUT AN AXIS NORMAL TO THE BASE, and THAT THE COMPONENT, NORMAL TO THE BASE, OF THE RESULTANT OF ALL FORCES ACTING, COINCIDE WITH SUCH AXIS. In no work heretofore has the writer found an expression for the factor sought, in terms of graphic functions, correctly fitting every condition as to shape of body and direction of applied forces—considering only plane bases, and granting, of course, that the intensities and points of application of the forces

PLATE I

FIG. 1

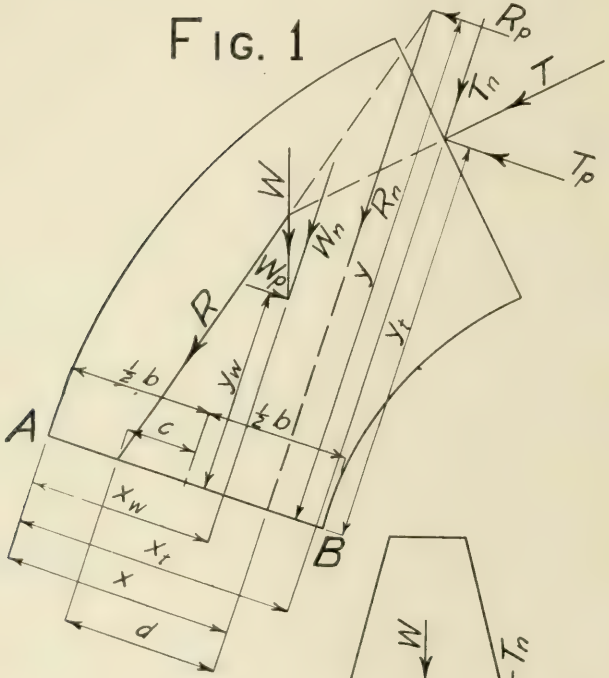
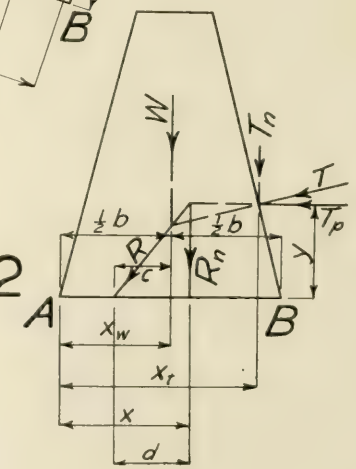


FIG. 2



are properly taken, as we are not here discussing the uncertainties of loads on arches, retaining walls, etc. A relation true for all cases, as lately deduced by the writer, is

$$\frac{\text{DISTANCE FROM EDGE OF ROTATION TO POINT WHERE RESULTANT OF ALL NORMAL COMPONENTS OF FORCES CUTS BASE}}{\text{DISTANCE FROM POINT WHERE RESULTANT OF ALL FORCES CUTS BASE TO POINT WHERE RESULTANT OF NORMAL COMPONENTS OF ALL FORCES CUTS BASE.}}$$

i. e., $\frac{x}{d}$ in all figures shown herewith. Following is the derivation of this real factor of safety against overturning.

Each figure represents a body, resting on its lower base A B, acted upon by an external thrust, T, and by its own weight, W. Stability against overturning of body about edge A is to be determined.

Nomenclature for both figures is viz:

T_p = Component of T parallel to A B
T_n = Component of T normal to A B
W_p = Component of W parallel to A B
W_n = Component of W normal to A B
R_p = Resultant of T_p and W_p
R_n = Resultant of T_n and W_n
R = Resultant of T and W, and of R_p and R_n.

Nomencalture of distance is self-evident.

Now, the factor sought is

$$\frac{W_n \cdot x_w + T_n \cdot x_t}{W_p \cdot y_w + T_p \cdot y_t} = \frac{R_n \cdot x}{R_p \cdot y}$$

But $R_p \cdot y = R_n \cdot d$

$$\therefore \text{Factor} = \frac{R_n \cdot x}{R_n \cdot d} = \frac{x}{d}$$

Examples will now be given showing the error, under certain conditions, of the first given expression for graphic application, and the correctness, at all times, of the expression just derived. Dams of various shapes best serve our purpose, owing to the character of liquid pressure. Since, in some writings, stress is placed upon the supposed relation $\frac{\frac{1}{2}b}{c}$ when the total resultant strikes the edge of the middle third of a rectangular base, thus making the foregoing expression $\frac{\frac{1}{2}b}{\frac{1}{6}b} = 3$, all the following examples are so chosen as to

PLATE II

FIG. 3

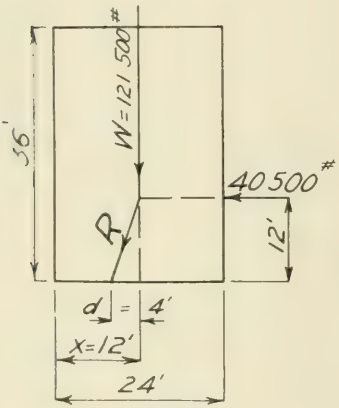


FIG. 4

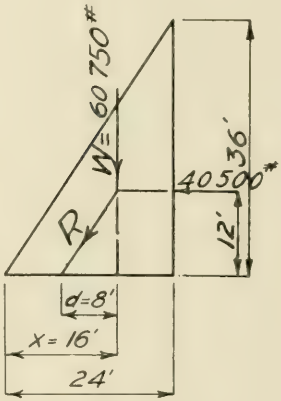


FIG. 5

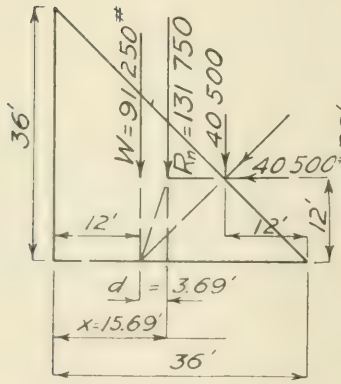
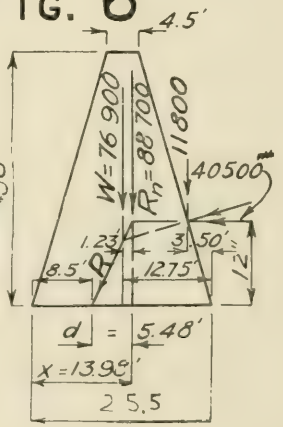


FIG. 6



have this condition fulfilled; the solutions show how widely the factor of safety against overturning may vary, though the relation last named be the same in all cases.

Each figure represents a section, one foot in breadth, of a dam having water full height on the right side.

Factors of stability against overturning, in both algebraic and graphic terms, are viz:

For Fig. 3. $$\frac{121\,500 \times 12}{40\,500 \times 12} = 3.00$$

$$\frac{x}{d} = \frac{12}{4} = 3.00$$

For Fig. 4. $$\frac{60\,750 \times 16}{40\,500 \times 12} = 2.00$$

$$\frac{x}{d} = \frac{16}{8} = 2.00$$

For Fig. 5. $$\frac{91\,250 \times 12 + 40\,500 \times 24}{40\,500 \times 12} = 4.25$$

$$\frac{x}{d} = \frac{15.69}{3.69} = 4.25$$

For Fig. 6. $$\frac{76\,900 \times 12.75 + 11800 \times 22}{40\,500 \times 12} = 2.55.$$

$$\frac{x}{d} = \frac{13.98}{5.48} = 2.55$$

These citations render clear that, except for symmetric bodies with section like Figs. 3 and 4, subject to no forces normal to the base other than their own weight, the mere position of the total resultant on the base tells nothing about the overturning stability, and that, for other shaped bodies the graphic solution of the problem is likely to be no shorter than the algebraic solution. They show, too, that the total resultant pressure may cut the edge of the middle third of the base, and yield a factor of from 2 to 5 for ordinary forms of dams and retaining walls. With other shapes of bodies and other inclinations of acting forces, the factor might be almost anything. Therefore, the writer contends that the only use made of the graphic fixing of resultant upon base line should be that of stress distribution especially for the condition with respect to the third points. If a resultant pressure falls within the middle third of a rectangular base, or the middle quarter of a circular base, we know that no tension or lifting exists on the side of the base farther from the point struck; if the resultant strikes the limit of such division, we know that unit pressure at the near edge is twice

what it would be were the normal pressure uniformly distributed, and that zero pressure exists at the far edge; and if the resultant is outside the middle division, we know that the maximum unit pressure at the near edge is greater than the amount last specified for that edge and that the other edge is in tension, if tension can exist, or is lifted off the support for the base: in any case the stresses may be determined, from scalar data, by methods the discussion of which is aside from the purpose of this article. These matters are discussed at this length only to show that, as the position of resultant pressure on the base of a body always tells directly something about maximum unit pressure, but seldom tells directly anything about stability against overturning, a graphical determination of this stability is not often advisable, or of value. Further, since any failure of a body so subjected is most liable to be by crushing rather than by overturning for we may have a high factor of stability against overturning and yet have dangerous stress in the case of a body with section such as Fig. 5, and since overturning cannot occur if resultant comes at all within the limits of the base, it is here contended that when graphic analysis finds the resultant within such limits all reference to stability against overturning might well be omitted from the treatment of ordinary structures, and safety against crushing and sliding alone be made the criteria of investigation.

SOME ORIENTAL NOTES.

STANLEY G. CUTLER, C. E., '08.

It is often said that the chief end of travel is to broaden one. The writer often deplored the fact, in the past, that his work never took him outside of Chicago, or, at any rate of Illinois, and it was largely the opportunity offered to see the Orient, which decided him to take the examination for Civil Engineer in the Philippine service. The knowledge that one is earning half pay for every day of sight seeing, and having all expenses paid in addition, is no drawback to the complete enjoyment of new sights.

At about ten o'clock in the morning of July 23rd, 1908, the "Aki Maru" drew up at the wharf in Yokohama, the principal seaport of Japan, and, after fifteen days of tossing green waves, the wonders of the Orient were open to us. Although it was raining we lost no time in spilling out onto the dock, and followed by the ever watchful eyes of the harbor inspectors, entered the city and hired jinrickishas, after being almost pulled to pieces by rival cabmen.

The writer's most constant companions in Japan were Buell, a Purdue E. E., a member of Tau Beta Pi, who was about to take a commission as lieutenant in the constabulary, Stewart, a recent graduate of Bloomington Normal, billed to the Bureau of Education, and West, of Brown University, the only other engineering appointee on our ship.

Yokohama has a fair street car system, with an interurban line connecting it to Tokio, the capital of the empire. The latter place has an excellent system with well formulated transfer service, the lines running across the city from end to end, as in Champaign. One fare, inside the city limits is four sen, or two cents gold, of which the government receives one-half sen. The fifteen mile ride between the seaport and the capital costs 19 sen or 9½ cents. The cars are smaller than the ones we use, the interurbans being the only ones equipped with double trucks and the ordinary street cars being of a type long since discarded in America. They are dirty, and crowded most of the time by Japs in every state of transition between primitive nativeness and complete Europeanization.

All Japanese lines are equipped with the double trolley system, and the city lines are arranged with loops at their ends so that the poles need not be reversed. The gage is American standard. The city cars make very fair speed, but the interurbans seem at no time to exceed 20 or 25 miles an hour.

The universal method in all modes of transportation is to give receipts with the fare, which are collected at the end of the ride. What penalty is attached to losing this slip was not determined.

After we had ridden a way into Tokio, the crowding became unbearable. Men and women seemed to be about on the same basis, but once in a while the latter gave up their seats to the former. No one ever moves over to make room, but if one enters and thinks there should be room between two seated passengers, he waves his hand at them, then promptly sits down between them, or, if they are slow, upon them. These customs being strange to American strap hangers, we felt ill at ease, so got off and found ourselves far from any base of communication, i. e., 'ricksha men, so wandered on on foot, in the frying sun.

One of the impressive sights in Tokio, which might well be described in books on masonry construction and stereotomy is the great wall around the Imperial Palace grounds. The fact that almost all Japanese masonry is laid in diagonal courses, makes stone cutting a much more difficult art than it is in the states. Whether those blocks of stone, as large as a small house were cut in place or not was not determined, but at any rate the section of the wall is very intricate, and the building of watch towers at intervals makes angles frequent.

This class of masonry construction looks most irrational at first glance, but it must be remembered that earthquake shocks, at the point of maximum intensity, consist in either horizontal or vertical movements, and that the element of danger lies in their tremendous impact force, capable of breaking the strongest bond as a swift blow with an ax will cut through a heavy limb. There are, therefore, two solutions presented to the architect—either to make his construction so elastic that it will give before the shock, or to offer the largest possible resisting area to it, the latter method being brought about by the diagonal coursing, which evidently will cause the stones to be lapped in relation to the direction of the force.

The other method of defeating the shocks is illustrated in lighter construction. The materials, of course, are bamboo, pine, and rattan, easily capable of bending, and tension connections are almost wholly avoided, some of the older buildings being entirely without nails. The foundations generally consist of individual stone blocks, on which rest the rounded ends of the building posts. Thus, while the whole structure may be displaced and thrown about considerably, there is no danger of tension fractures with vertical disturbances, or flexure with horizontal shocks.

There is a general idea in the states that a modern Japanese city presents the same appearance as those at home, but nothing is further from the case. Their sky lines are uniformly low, seismic disturbances limiting the height of the buildings to two or three stories. A few of the government buildings are massive stone affairs, in which the greatest care is taken in jointing, although very few diagonal courses are seen in building construction.

Later on we found 'rickshas. The idea that everyone in Japan

speaks English is a snare and a delusion. One generally makes contracts with the 'ricksha men by means of an open watch and handful of change. The price is usually determined by the workability of the passenger—an average amount is 50 sen an hour in Tokio, and 20 sen an hour in the other large cities. Our men took us into the Imperial Palace grounds, in which there are some marvelous examples of cyclopean masonry. The moat about the inner grounds is filled by the waters of a small river, which falls over great artificial falls and rapids and is crossed by one masonry arch bridge of most beautiful design. We attempted, with American presumption, to enter the Holy of Holies, but were warned away at the point of the bayonet.

We returned to Yokohama on the railway. The fare was 45 sen, or 22½ cents second class. There is great difference between first and second class accommodations; first class cars are white and second class are blue. The engines are of the type used on the Illinois Central lines in Chicago, with four drivers and two pilot wheels. They burn the softest slack and smoke profusely. The train divisions are about thirty miles—an hour's run. The first and second class coaches are double trucked with end entrances, while the third class are single trucked, with side doors. Each coach being very light, the trains are made up of a great number of them, the Tokio-Yokohama express having twenty coaches.

The ballast in this part of the line was of cinders, and fairly well maintained. The slow speed of the trains makes a block system unnecessary, and, as far as we could tell, the switches and signals were all set by hand.

The official railway gage in Japan is 3 ft. 6 in., which makes a peculiar appearance where steam and electric lines cross. The gage is sufficient for the present traffic and makes construction much lighter. The average depth of bridge girders is 36 inches and truss bridges must have been computed for about E 20. It is said that the narrow gage makes dining and sleeping cars rather uncomfortable.

Speaking of gages reminds the writer of an interesting conversation with an Australian gentleman in which he described the still existing "gage war" in the island continent. The mutual jealousy between the colonies in the early times caused them to adopt different standards, and now they find themselves faced by the problem of frequent transhipment of a large amount of freight or the condemnation of hundreds of miles of track. Two colonies now have 5 foot gage; two, the 3 ft. 6 in.; one 4 ft. 6 in.; and one, standard American gage. It is evident something must soon be done to relieve the tension.

The last morning the writer spent in Yokohama, he took an early morning walk. Coming to a small commercial track strewed

with white dust, he smelt concrete in the air and followed on. Soon a "thump! thump! thump!" mingled with a low, monotonous chant was heard—suggesting that some betrayer of Nippon military secrets was being executed to slow music. The mysterious sound proved to be a cement mill, consisting of about twenty women with long narrow pestles, which they brought down into a steel trough in unison, singing, meanwhile, a succession of three different notes, all minors. A little ways further on were very complicated molds, in which all sorts of ornamental cornice blocks were being cast of crushed stone concrete.

On the way out of the harbor we got a good view of the defenses, built on a small island, although, of course, there was a strict taboo on cameras and sketch books.

After stopping at Kobe we moved on to Moji, through the Inland Sea—the pride of Japanese artists, and deservedly. Our ship coaled at Moji. Early in the morning we were surrounded by a host of big sampans, swarming with half (or a greater fraction) naked natives. A sampan was moored at each coaling port, and a plank so placed that a line of men could be formed from the coal boats to the ship. Down in the sampan several coolies scooped coal into shallow baskets, which were passed up the line and emptied through the ports. Women worked side by side with the men. These baskets, filled, weighed about thirty pounds and were passed up at the rate of about one in five seconds. At six o'clock the sampans were emptied, the coolies stripped without the least compunction and plunged into the bay for their evening bath.

In this connection it might be mentioned that coaling was done somewhat similarly in Hong Kong, except that two men handled a basket at a time, these latter weighing about 70 pounds. The ship's officers said that this method was cheaper in the Orient than any form of mechanical bucket or scoop, and just as rapid.

At Nagasaki, West and the writer made a foolish boast to climb the hills north of town, so started out and were at last rewarded by a few primitive sights. The rice fields in Japan are more highly cultivated than those in the Philippines, reaching far up the hill slopes. The fields on the Nagasaki hills were irrigated by mountain streams, which flow into the highest ones and thence down a series of stepped paddies formed between stone dykes. The water was well utilized. After irrigation, water power, the field drainage being carried down in bamboo pipes to large wheels, each of which, being supplied by three pipes, thus being overshot, breast, and undershot; then water supply for the upper town, the women carrying it up to the houses in bamboo pails, while the little children bathe in the wide stretches; then sewerage further down, and by the time it reaches the sea it is pretty tired, bad smelling water. This method of irrigation,

makes the hills along the Inland Sea look like piles of green coursed masonry.

Nagasaki is the coaling port for the United States transports, therefore is well supplied with saloons and other conveniences for the jolly tars. We were not specially sorry to leave it. After two days on the beautiful China Sea, we reached Hong Kong on Aug. 5th, where we remained two days.

The city of Victoria, Hongkong, is surrounded by precipitous bluffs, and the care of the storm water during typhoons is a very difficult proposition. The British army engineers have built long masonry storm water channels down the sides of the bluff, at average slopes of about one to one, all converging in a central basin or series of basins of concrete, about half way up the hill. The water is allowed to stand in these settling basins till fairly clear, when it is piped down into the city with a head of about 200 feet. This water is not used for drinking purposes by Europeans.

Road building in Hongkong presents some difficulties, since, to go to the Peak Hotel requires an ascent of 1800 feet in a horizontal distance of about half a mile. This, of course, is accomplished by see-sawing the road up the bluff, crossing drainage ditches and deep ravines on the way. Their final appearance, regularly crowned, and edged with little concrete storm channels is a tribute to British engineering.

No one, however, uses these roads except fools and coolies. The tram starts about 100 ft. above the sea and climbs at an average grade of about forty degrees. The cars are two in number, and run on an endless chain, so that they cross half way up the ascent. The control is all from the power house at the top, where, in front of the operator, as a map of the line, on which pointers indicate the position of the cars. When a pointer approaches a station the cable is stopped until the conductor rings his bell. This necessitates the building of very long platforms, also in the stopping of both cars. It is a rather alarming sensation to slow down and stop, without visible reason, above some yawning gully. It gives one the notion that perhaps the cable has broken and he will begin to go down soon, to his great discomfort. At the top the gentlemanly conductor showed us the braking apparatus which consists in a bar so connected that, if the tension on the cable should be released, the motion of the wheels would clamp the brake onto them and would continue to clamp it tighter, as long as the wheels were in motion. It was claimed that this apparatus would stop the car in an inappreciable distance. First class fare on the tram was 50 cents local currency, or 25 cents gold, per round trip.

On the following day the writer took occasion to cross to the mainland where it was said that the Canton railway was being constructed. He introduced himself to the engineers present, one of whom was the concrete foreman for the company and one the gov-

ernment inspector. One gentleman inquired what part of the states he hailed from, and he was surprised that "Illinois" carried no impression to the questioner until it occurred to him that Lancaster, or York, would not be very definite locations to him. On propounding "Chicago," however, they understood. "Oh yes, the city the beef comes from." One of them had visited in Milwaukee at one time, so as the writer has connections in that city, a bond of common interest was established.

The concrete for the sea wall was being put in very dry. All the work was done by coolie labor, men doing the mixing and tamping and receiving 35 cents Mex. per day, while the women carried the concrete from the mixers to the forms in baskets at 25 cents per day, keeping up a continuous stream.

The writer was rather disappointed that he had not read Prof. Baker's "Masonry" a little more thoroughly, as one of the first topics of conversation was as to whether salt water concrete was inferior to fresh, and he could not say what the standard work said on the matter. However, the British engineers were using salt water right along, and said it appeared to be satisfactory, although it set slowly. They appeared rather dissatisfied with the coolie labor, saying that, when not under the foreman's very eyes, it was very inefficient.

On the same day the harbor defenses were visited. The ammunition hoists and carriers are very ingeniusly arranged to convey the ordnance supplies from the water's edge to the highest of the big guns. Victoria is fitly called the "Gibraltar of the Orient."

On Aug. 10th, Sunday morning, the writer landed in Manila, and on the following morning reported for duty at the office of the Bureau of Public Works, being assigned to the irrigation department under H. B. Kirkpatric, Ill., '99, irrigation engineer. Although the first week was considerably broken up by two legal holidays, the routine soon became more familiar and the strangeness wore off.

The organization of the Bureau of Public Works provides for three different arrangements of headquarters. The Department of Bridges is located in Manila, where all its work is done, so that its engineers usually seek lodgings in the city, either in the American quarter, called the Ermita, in the Spanish districts of San Sebastian or San Miguel, or in the walled city (Intramuros) where the office of the Bureau is located, either obtaining board in American boarding houses, or working a combination of batching and eating at the hotels. By practicing economy one can live thus for very little more than good board would cost in the states.

Some of the appointees are at once detailed to the provinces, where their headquarters are usually in the provincial capitals. In such a case they can generally find a room with some Filipino family in town and board with the American mess, which is generally to be found in the large centers.

The engineers of the irrigation and road departments are sent out in parties of three or four, and, while outside of Manila are paid all traveling and sustenance expenses. When in Manila, completing reports or waiting orders, they are, of course, at their own expense, and usually live at one of the hotels, or else keep a room all the time, locking it up when out of town.

At the present time the new assistant engineers form a most congenial crowd coming from almost every college in the country. There are several men from Harvard, two from Boston Tech., several from Michigan, one from Wisconsin, two from Purdue, and so forth. One of Prof. Sanborn's students, S. W. Moore, Tufts '08, has been working on the same project as the writer for some time. There are a large number of college men in Manila, the University Club being one of the most flourishing in the city, while some of the fraternities, among them Sigma Chi and Alpha Tau Omega have alumni chapter located there.

The personel of field parties generally consists of a chief engineer and two assistants, to which one Filipino "pensionado" is sometimes added. The selection of the relative positions in such a party is dependent upon the previous experience of the engineers. In any case, the American engineers generally have plenty of varied and instructive work. A full sized field party generally employs from five to eight natives when in good working order. The idea that everyone speaks Spanish or English in the Philippines is a fallacy—the most useful language, if one does not know Tagalog or Viscayan is a combination of gestures.

It might be supposed that such a force would be very inefficient, but the opposite is the case. The men can be sent anywhere, into deep rice swamps or muddy river bottoms. A favorite system in use in controling stadia men is to give each man a number, and then direct him by flagging his number in the desired direction. In this way the recorder can keep three stadia men in as rapid motion as the transit man can read them.

There are some points about field conduct here that might seem strange to engineers in the states. The instrument is always shielded by a big umbrella—a native carries the instrument. It might seem that these customs would effeminize, but it is exceedingly difficult for the new American to even carry himself across the mud and dykes in safety.

The floods in the islands are said by experienced engineers to be the most sudden and voluminous in the world. The writer awoke one morning to find that the little river, which had been flowing quietly in a deep gulch the night before, had grown to a torrent half a mile wide, running like a mill sluice. The water continued to rise until it surrounded the house to the depth of a foot and covered the road at an elevation of about fourteen feet above the normal. This

flood was caused by a continued storm, or "baggio" lasting for about three days, and all speed was made to get data concerning it by means of high water stakes and velocity estimations. The ordinary velocity of the river is 3 feet per sec., section area 50 sq. ft., discharge 120 cu. feet per sec., while at the time of the flood the velocity was 10 feet per sec., section area 5300 sq. ft., discharge 36,000 cu. ft. per sec. Although the cause of such unusual floods is apparent, the rivers often increase their discharge four or five times without visible reason. Such increases are usually due to storms in the mountains in which the streams rise.

The hope of every American arrival is to return to the states via Europe. At the end of two years' satisfactory service his traveling expenses and half pay, for the time spent coming over plus two extra months full pay are due him; at the end of three years an additional month's full pay and half pay for the time required to return are due; and even the smallest of these amounts would be sufficient to carry him with economy through Asia and Europe, and across the Atlantic. So one of the most fruitful topics of discussion for the recent arrivals is the relative desirability of the various routes back again.

LIGHTNING.

ELLERY B. PAINÉ, M. S., E. E.
Assistant Professor of Electrical Engineering.

A century and a half ago when Franklin made his famous kite experiment it was generally believed that lightning was the explosion of vapors which collected in the atmosphere under certain conditions. Franklin's proof that lightning is electrical in its nature stopped much speculation over the chemical composition of those vapors and the way in which they became ignited to produce the lightning explosions. Since Franklin's time scientists have considered lightning similar to the sparks of experimental electrical apparatus except that the lightning is on a vastly magnified scale.

During the last hundred years many men have tried to learn the secret of atmospheric electrification. Many hypotheses have been proposed in explanation of the electric charge of the air. Friction of air currents, evaporation of moisture, dashing of ocean waves against the rocky shores are known to produce electrification. We must admit, however, that we do not understand what produces atmospheric electrification.

Many who have written on the subject have classified lightning in three forms: zig-zag, sheet, and ball lightning. We now think sheet lightning is unlike the first named form only in having the direct light from the flash hidden from the eye. In this form of lightning one sees the light reflected from the clouds. Many marvelous accounts of the slowly moving ball lightning have been recorded. Modern scientists who had never seen this form of lightning were inclined to be skeptical. The discovery by Prof. Righi of Bologna* of a method of producing such discharges experimentally leaves us little ground for doubting the existence of ball or globular lightning.

Dove was perhaps the first to attempt to measure the time taken for a lightning stroke.* He used a rapidly revolving disc marked with colored sectors. He discovered that lightning discharges are usually made up of several component flashes. His experiments showed that each separate flash was apparently instantaneous. Four years ago Schmidt made a similar investigation* and found that the separate flashes were completed in less than 1-30000 second.

In recent years the camera has been of much value in lightning study. The first work done in photographing lightning appears

*Electrical Review, London, April 3, 1896.
*Poggendorff Annalen, 1835. S. 371.
*Elektrotechnische Zeitschrift Sept. 28, 1905.

to have been that of Prof. Keyser at Bonn.* Photographs of lightning taken with stationary cameras sometimes showed the discharge separated into its component flashes by the side drift of the air currents. This suggested to Prof. Weber of Kiel the use of a revolving camera which would allow the impressions of the various discharges to be still more widely separated on the photographic plate.* Later Dr. Walter of Hamburg developed and used a rotating camera.* Similar work has been done in the United States by Larson.*

The camera investigations have shown that lightning strokes are usually composed of not less than five or six discharges along nearly the same path. Some strokes are made up of as many as forty flashes. The time required for complete discharge sometimes is as great as .6 second.

In 1858 Feddersen found proof of the oscillatory nature of Leyden jar discharges. It is thought that lightning discharges also are oscillatory but no direct proof has ever been made. Experiments made to solve this problem have not been conclusive.*

Estimates of the voltage necessary for lightning, based on data obtained from such discharges as may be produced in the laboratory, lead to values which appear unreasonably large. Lodge estimates the potential difference required for a lightning stroke one mile long as 5,000 million volts.* Steinmetz calls attention to the fact that with such a potential difference as this the corona effect would be very marked. It is probable that long strokes may take place with voltages far smaller than the estimate quoted. It is known that a dielectric breaks down at a point where the potential gradient at that place is too great. That is a dielectric can not withstand an electric stress greater than that caused by a certain number of volts per inch. The exact value of the limiting potential gradient varies with the character of the dielectric. If in the atmosphere we have, even for a short distance, a too great potential gradient, discharge will take place. Because of the lowering of the potential at one end of the discharge path the potential gradient may become too great at that point, so that the discharge extends over another space. In this way it appears reasonable that a long discharge may result, although the initial difference of potential is sufficient to cause discharge over only a much shorter path. This explains how a stroke of lightning may occur wholly within a single cloud. It was formerly thought that lightning occurred only between two clouds or between cloud and earth.

Hence we see that the condition needed for lightning discharge

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*Wiedermann Annalen, 1885. P. 131.
*Bericht der Konigl. Akad. 1889. P. 781.
*Physikalische Zeitschrift 3, S. 168.
*Annual Report Smithsonian Institution, 1905.
*Physikalische Zeitschrift 2 P. 715.
*Lightning Conductors and Lightning Guards. Page 9.

is that the potential gradient along a path through the atmosphere be greater than the air can withstand.

It has been found that under normal conditions the potential gradient along a vertical line from the earth's surface is several hundred volts per foot. As stated before we are not certain what causes this change of potential at different elevations. Particles of water formed by condensation of moisture in the atmosphere will have potentials equal to that of the air at the place of formation. As numbers of these small particles combine into larger drops the potential of the drop increases with increase of size, because the capacity of the drop increases only as the radius, while the total quantity of electricity increases as the mass or the third power of the radius. Hence great condensation will cause the potential of the drops of water to become greater than the potential of drops at a point of less condensation. If we have within a cloud quite unequal condensation at various points we may have potential gradients so great that the air along certain paths is broken down. We have these conditions most frequently in the case of the gusty clouds formed near the earth on hot summer days.

The great heating effect of lightning indicates that its current strength is high. Dr. Prockels has investigated the strength of current in lightning rods which had been struck by lightning.* The tests reported indicate currents of ten thousand amperes or more.

The total energy of a single flash of lightning has been estimated by Steinmetz as 10,000 K. W. seconds. This estimate is based on the energy required to produce illumination equal to that given during a lightning stroke.*

Lodge arrives at about the same result from the calculation of the amount of energy stored in a certain volume of air due to the maximum electric tension air is able to withstand.

Our knowledge of lightning is far from complete. The loss of life and property each year because of lightning is large. In the United States alone the loss, according to government records, amounts to several hundred lives and between one and two million dollars worth of property. One of the great problems of the electrical engineer is the protection of electrical apparatus from lightning troubles. This problem has assumed greater proportions since the use of long distance high potential transmission lines. A better understanding of lightning is much to be desired.

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*Wiederman's Annalen. 65. S. 458.
*National Electric Light Association, 1907. v. 1, P. 361.

A PRECISION SLIDE-RULE.

A. N. LURIE, M. E., '09.
Junior Member W. S. E.

The Mannheim slide-rule, as arranged fifty or sixty years ago by Col. Mannheim of the Austrian Engineer corps, has served the engineer and scientist for half a century, as an invaluable instrument. The facility with which it may be operated, its value as a saver of time and of mental and manual labor, if pushing a pencil may be dignified by the term *manual labor*, has won this tool a place in the kit of every progressive engineer. The item, however, which has probably made it of greater value to the engineer than to the scientist, is that in the great majority of those problems which occur in engineering practice its accuracy is sufficient.

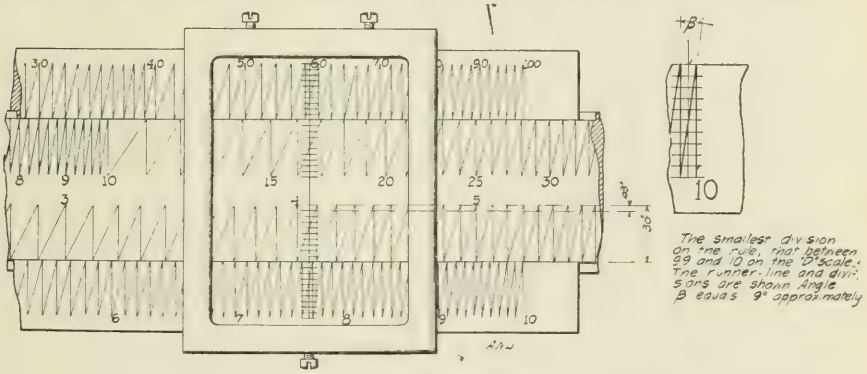
The engineer in general understands that without going to any great pains the error in any reading can be kept as low as one per cent, that is, the first doubtful figure, varying by one, plus or minus, is the third significant digit. To repeat, this degree of accuracy is sufficient, for in general engineering calculations we do not measure the inside diameters of our stacks with micrometers, nor a carload of coal in milligrams,—inches and hundred weights will do.

But to say that this degree of accuracy, illustrated figuratively, is sufficient for most engineering work, does not indicate that it will pass for all. In the bridge shop, the templet maker has no use for a dimension which reads 8′ — 1.2″ about. He must have the dimensions accurate to within a sixteenth of an inch, so that the chords, struts and other members may go together out in the field. In laying out a connecting rod, we do not say that the distance, center to center, of brasses is 5′ — 2.7″ about, implying that it may be 5′ — 2.6″ or perhaps 5′ — 2.8″. The distance is either 5′ — 2.7″ exactly, or 5′ — 2¾″, or, whatever the case may be. A quarter of an inch is a great item at times. They say a quarter of an inch on the end of Cleopatra's nose would have altered the history of the world; but that is ancient history.

With the idea in mind of increasing the accuracy of the slide-rule, and at the same time of avoiding an involved instrument, the writer stumbled upon a device which he believes will make a more accurate and desirable tool. The accompanying drawing shows a full size layout of the middle portion of the scales. The fundamental principle is not a new one by any means, and is used in some forms of physical and engineering manometers, as for example, in the inclined-tube draft-gage. In this slide-rule, it consists substantially of lengthening the graduations several hundred per cent, without increasing the length of the rule. A perpendicular to the longitudinal center-line is erected at each major division, a major division being, for example, the distance between 5.1 and 5.2. A series of perpendiculars, all of the same length, is formed and lines are drawn

from that extremity of each perpendicular farthest from the slide to the foot of the next one. These lines, the hypothenuses of a series of right triangles whose bases are the logarithmic divisions, and whose altitudes a given distance, now become our scale proper. Horizontal graduations on the runner-glass which are intersected at right angles by the hair-line divide the perpendiculars, and of course at the same time the hypothenuses into ten equal divisions.

In the rule wherein the distance between indices is 25 cm., known commercially as the "ten inch rule," the increase in scale length in the C and D or lower scales will be a little oevr two hundred per cent, while in the upper, or A and B scales it will probably reach as much as three hundred per cent or more. The length of the perpendiculars is three tenths of an inch, making each division on the runner glass three one hundredths of an inch or about one thirty second. This makes the rule easy to read. The smallest angle which occurs between the hair-line and any hypothenuse is that on the C and D scales, between the divisions 9.9 and 10. This angle



A Precision Slide Rule.

is nine degrees. The runner glass is very thin and close to the scales, so as to avoid parallax as much as possible. It is adjusted by four small set screws, two above and two below. The operation of this rule and the Mannheim are identical.

When the writer first showed this design to a few friends, some thought it was a good idea and feasible, others made sarcastic remarks and were solicitous regarding his mental welfare. One ventured that a few wise men were still living before the writer was born and if they had not found this scheme practical it stood to reason that it must be valueless.

Personally the writer believes this idea is more than an oratorical safety valve. It increases the accuracy from one in a hundred to one in a thousand. This instrument is easier to construct, than the Mannheim, as it reduces the number of lines in the scale from 1284 to 820, or a reduction of nearly 36 per cent. Thus we have a simpler and at the same time more accurate instrument.

THE USE OF SELENIUM IN PHOTOMETRY.

JOEL STEBBINS, Ph. D.
Assistant Professor of Astronomy.

It has long been known that the crystalline form of selenium changes its electrical resistance when exposed to light. Physicists and electricians have made various attempts to utilize this property in devising some form of selenium photometer, but so far without success. Evidently there would be a great demand for an instrument which would indicate the candle power of a light as conveniently and accurately as volts and amperes are now measured. Imagine the revolution in the electric lighting industry, if a portable instrument were devised, which on being held at a certain distance from a light, would give at once its actual candle power! About two years ago the writer and Dr. F. C. Brown began some experiments on the use of selenium cells in photometry, our ultimate object being to measure the light of stars. Although this phase of the work is not of direct interest to engineers, there are a number of difficulties which we encountered and overcame, which arise in any use of selenium for measuring light intensity.

When selenium is immersed in certain liquids, the action of light produces an electromotive force, and for this reason the crystalline form with electrodes attached has come to be called a "selenium cell," though the more logical name of "selenium bridge" has been suggested.

The usual form of a cell consists of two wires wound in a double spiral about a flat insulator, the spaces on one face being filled with selenium which is properly treated to make it sensitive to light. Fig. 1 shows such a cell mounted in a hard rubber case.

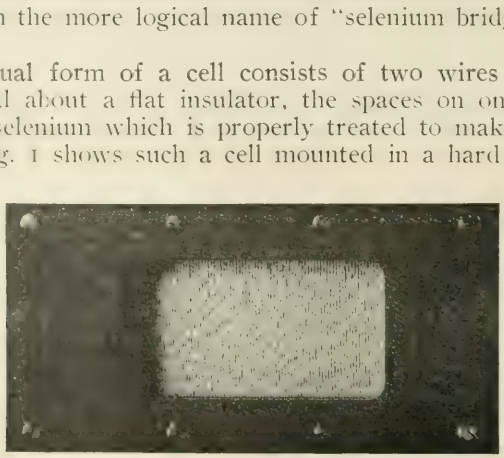


Fig. 1. Selenium Cell by Giltay.

The occulting slide has been removed, and the terminals are brought out at the back of the case. In this arrangement the selenium ele-

ments are connected in multiple, which method is adopted because of the high resistance of selenium. The cell in the figure has a resistance of about one million ohms, and for cells of smaller area the resistance runs up to several hundred megohms.

There are different methods of sensitizing the selenium, one of which is to melt it at 217° C., and then allow it to crystallize between 100° and 200° C. The best cells are made by Giltay of Delft, Holland, and Ruhmer of Berlin, but neither of these men has divulged his method of manufacture. In a letter to the writer, Mr. Giltay has said that his method is sometimes a secret, even to himself, for after thirty years of experience in making cells, he often has surprises of the most disagreeable kind.

It is customary to rate the sensibility of a cell by the ratio of its resistance in the dark to the resistance on exposure close to a 16 c.p. light. Thus a cell with an initial resistance of 1,000,000 ohms which drops to 100,000 ohms in the light, has a sensibility of 10 to 1, and would be called a fairly good cell. Our best cell is rated at about 100 to 1.

After exposure a cell does not regain its original resistance immediately, but requires as long as several hours for complete recovery from the effect of sunlight. We have found that when the light action has changed the resistance by only one quarter of one per cent, about two minutes are required for recovery.

Perhaps the one pecularity which has prevented the general use of selenium, is that it differs from the eye in color sensibility. When sunlight is drawn out in to a spectrum, the normal eye perceives the colors from violet to red, and the maximum intensity is in the yellow, while with selenium the greatest light effect is near the red end of the spectrum. As a result a white or bluish source such as the electric arc, may have less effect upon selenium than a yellowish incandescent light, although the former appears far more brilliant to the eye, and it is the effective visual intensity which is usually desired in photometric results. There should presumably be no great difficulty in finding a combination of colored screens which when placed in front of a selenium cell would render the effect of different colors about the same as for the eye, but we have found that various cells are much unlike in their color-sensibility. In Fig. 2 are represented the color-sensibility curves of four cells, where ordinates represent the action of light in terms of galvanometer deflections, and abscissas are wave-lengths or colors. The visual spectrum, violet to red, extends approximately from wave-length 3900 to 7000, with maximum intensity at about 6000. In determining the curves the sun was the source, and the light passed through a grating spectroscope attached to the 12-inch refractor. Each cell was exposed successively to different parts of the spectrum, and as nearly as possible the conditions were the same for all cells. Although these curves are not

absolute in the sense of being independent of the source, or of the instrument, they show the relative action of the same light upon different cells. It will be seen that the curves of the Giltay cells have

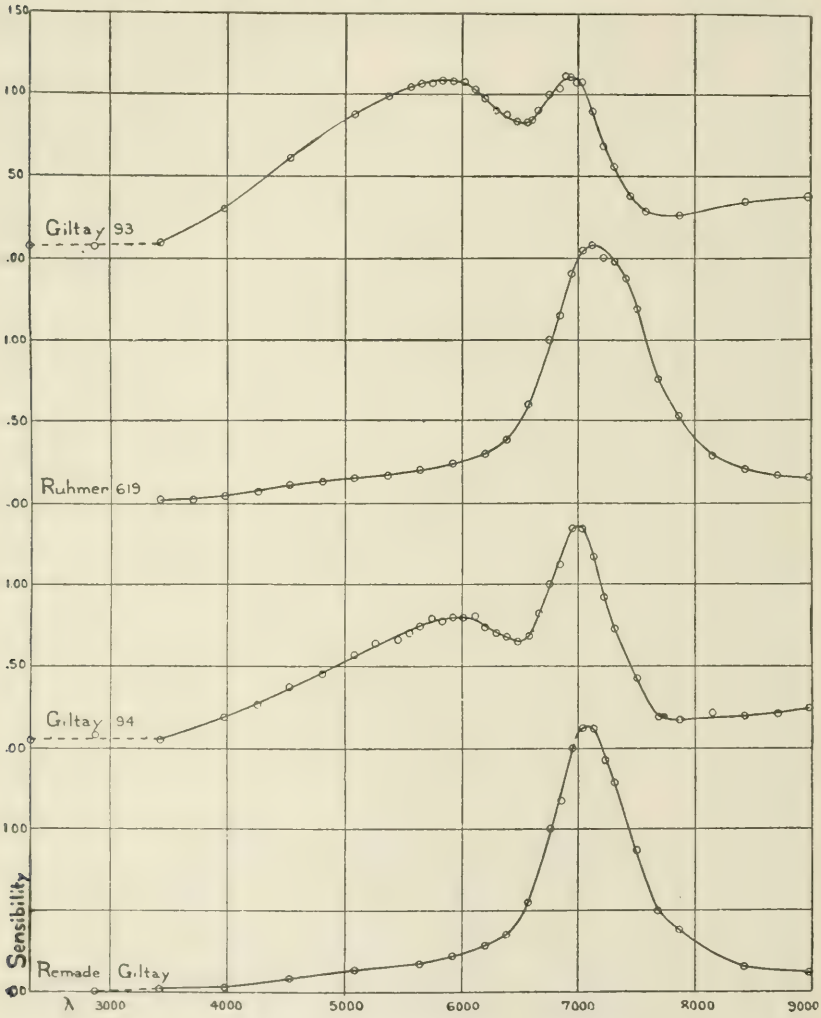


Fig. 2. Curves of Color-Sensibility of Selenium Cells.

two maxima, while the Ruhmer curve has but one. We had destroyed the sensibility of the fourth cell, in some previous experiments, and it was reannealed by Dr. Brown.

Another peculiarity of selenium is its great variation with tem-

perature. At ordinary temperatures an increase of 1° C. will lower the resistance of a cell by about 5%, and it is thus possible to use selenium as a sensitive thermometer. One of the greatest difficulties we have encountered has been the elimination of temperature effects. For some reason or other, we have found no definite reference to this trouble in the published work of other investigators, but perhaps this is because we have been working with lights so faint that the temperature effects are more conspicuous.

Other agencies which affect the resistance of selenium are the proximity of radium, also hydrogen peroxide; and, what is especially interesting, the resistance decreases considerably with increase of the electromotive force applied in measuring the resistance.

Before taking up the procedure in measures of starlight, it may be worth while to indicate wherein the ordinary visual methods are not satisfactory. The stars are so faint that an observer can not measure their light by letting it fall upon a screen, but must view the objects directly. One method is to use a small light to form an artificial star, and to compare this successively with the images of real stars seen in the telescope. In any method, what the observer does is to compare two sources, visible at the same time, and vary one or both until they appear equal. Unfortunately no eye can infallibly distinguish between two lights which differ as much as ten per cent, though the mean of several measurements may be accurate to five per cent or less. The relative error in photometric measures is far greater than the error in measures of mass or length, and this will be true so long as the human eye is used in judging of light intensity.

When photographic methods were first applied to astronomical work it was hoped that the relative brightness and changes of the stars could be more accurately determined, but experience has shown that measures of the star images on a photographic negative do not give better results than those from direct visual estimates. Because of the permanent recording value of a photograph, however, there is a wide application of the camera to astronomical photometry. In commercial work, there has been little or no use of photography for determining candle power; perhaps principally because the method is slow, but also because silver salts are most sensitive to blue and violet light. In astronomical applications it is more a question of determining the variations of light sources, and the matter of color sensibility is, in many cases, not of prime importance.

In our work on starlight, a cell about 10 mm. square is placed near the focus of the 12-inch objective of the telescope, which increases the light action of a star about 700 times. The selenium cell is connected as one arm of a Wheatstone bridge, and when the sensitive surface is exposed to a star, a deflection of the galvanometer is produced. One observer in the dome directs the telescope, and makes the exposures, while the other is stationed below where

wires from the cell are carried to the galvanometer and resistance boxes. Following are the conditions of the experiment on a certain night. The resistance of the selenium cell was 4 000 000 ohms, the ratio arms of the bridge were 10 000 and 10 ohms, and the variable arm was 4000 ohms. Current was supplied by 10 dry cells giving 14 volts. The galvanometer is of the D'Arsonval type, its resistance being 500 ohms, period 5 seconds, and the figure of merit, or current required to produce 1 mm. deflection at 1 meter scale distance, is 2.5×10^{-10} amperes. The scale was placed at 2 meters, and with a good view telescope was read to 0.1 mm. Under these conditions a 10 second exposure to the "North Star" or Polaris gives a deflection of 4 mm. The zero reading of the galvanometer will change visibly during 10 seconds, often as much as 1 mm., thus introducing an error of 25 per cent into the result. For stars brighter than Polaris, the relative error is less; in some cases our results agree within 1 per cent, but for faint stars the irregularities may be larger than the light effects.

A simple computation shows that the change of the galvanometer reading by 1 mm. can be accounted for by a temperature variation of only 0.001° C. and it is therefore of the utmost importance to keep the selenium at a constant temperature. By enclosing the cell in a case where the temperature is regulated by a thermostat, much of the unsteadiness and drift of the galvanometer are eliminated, but there are still some outstanding irregularities. The difficulty seems to lie in the heating effect of the current through the cell, which though small is enough to account for the trouble. As near as we can estimate, the 14 volts through 4 000 000 ohms is sufficient to raise the temperature of the small amount of selenium by about 0.1° C. in 10 seconds, and the irregular conduction and radiation of this heat away from the selenium may easily cause the observed variations of resistance. Just at present we are trying the experiment of placing a cell in a kerosene bath, which will in part assist in eliminating the effect of outside changes of temperature, but more especially should carry away from the selenium the heat which is generated by the current.

It is easy to increase the deflections from stars, by adding more battery, but the irregularities are magnified as well, and there is no practical gain. In the course of two years, however, the disturbing factors have been so diminished, that where we once obtained only 1 mm. deflection, it is now possible to increase the current so as to get about 200 mm. from the same star. We hope to secure still better results and each increase of sensibility will enable us to carry the work to fainter stars.

When the writer and Dr. Brown first took up the work with selenium, the cells then available were not sensitive enough for starlight, but we found that the moon was bright enough to measure, even without a telescope. On every clear night for two months

we compared the moon with a standard candle, exposing a selenium cell first to one source, then to the other, and moving the candle back and forth so as to determine at what distance its light was equal to that of the moon. Roughly speaking we found that a surface will be illuminated by the full moon about the same as when it is placed 1 meter distance from a source of one-fifth of a candle-power. It is well known that the full moon is more than twice as bright as the half moon, and with selenium cells we found that the ratio is about 9 to 1, and that the full moon is about 30 times as bright as the crescent moon which is of one-fourth the area. We determined another fact which so far as we know was never recorded by visual observers: the moon is slightly brighter before than after the full phase. A casual glance will show any one that the west half of the moon has fewer dark markings than the eastern portion, and we should therefore expect a difference depending upon which side is illuminated.

In this short account of the use of selenium, I have touched only upon the main features of the application to astronomical work. Perhaps to the general reader, the scientific importance of measures of starlight is not evident. Most of our ideas of the form and extent of the universe come from a statistical study of the brightness of stars. It seems safe to assume that the bright stars as a class are nearer to us than the faint ones, and for the great majority of the millions of stars visible in our telescopes, the only clew to their distance is their relative light. It requires centuries to measure the motion of a star, years to find its distance, but the brightness can be determined in a few minutes.

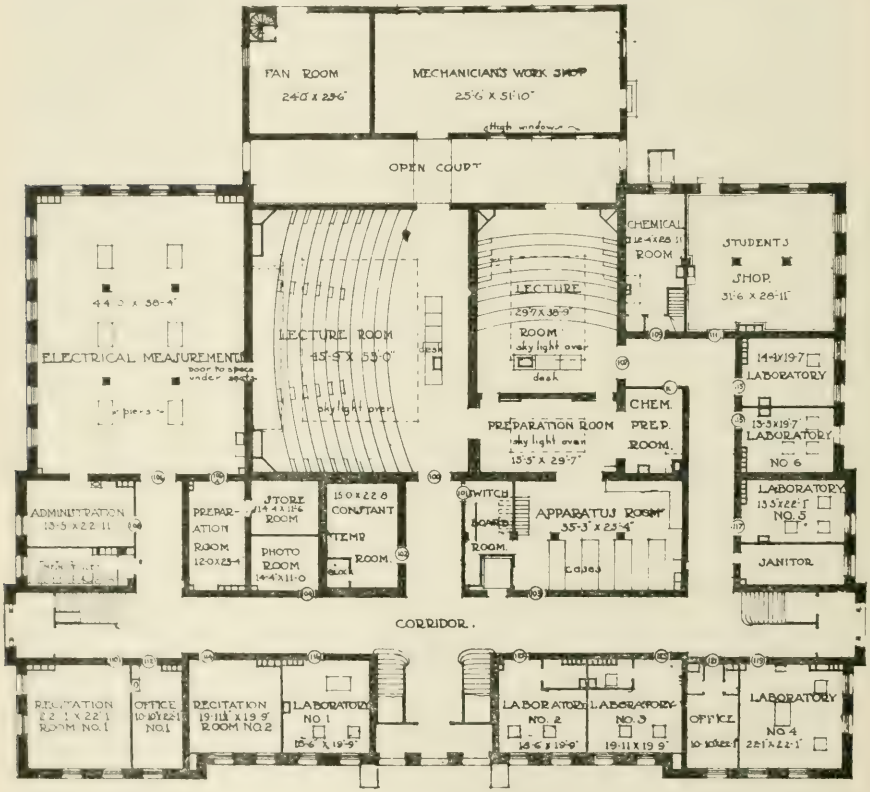
Again, the first evidence that other stars than the sun have planets was derived from photometric measures. It was found that some stars, usually of constant light, become fainter at definite intervals and then resume their normal intensity. In each case this indicates the presence of an unseen dark body, which, revolving about its primary, passes between the earth and the star, and causes an eclipse. There are several thousand of these so called variable stars in the sky, though not many of them are explained by the simple eclipsing effect of a dark satellite, and the study of these interesting objects is little more than begun.

The first work on selenium by Dr. F. C. Brown and the writer was done in the physics laboratory. Since Dr. Brown's departure, the investigation has been continued at the observatory, though I have had, from time to time, the benefit of the advice and assistance of different members of the physics department. The actual work on stars always requires two observers, and in this part I have had the efficient assistance of Mr. B. O. Brown and Dr. F. W. Reed.

THE LABORATORY OF PHYSICS.

A. P. CARMAN, A. M., D. Sc.

The building for physics which the University of Illinois will open in September, 1909, is notable as an addition to the University's

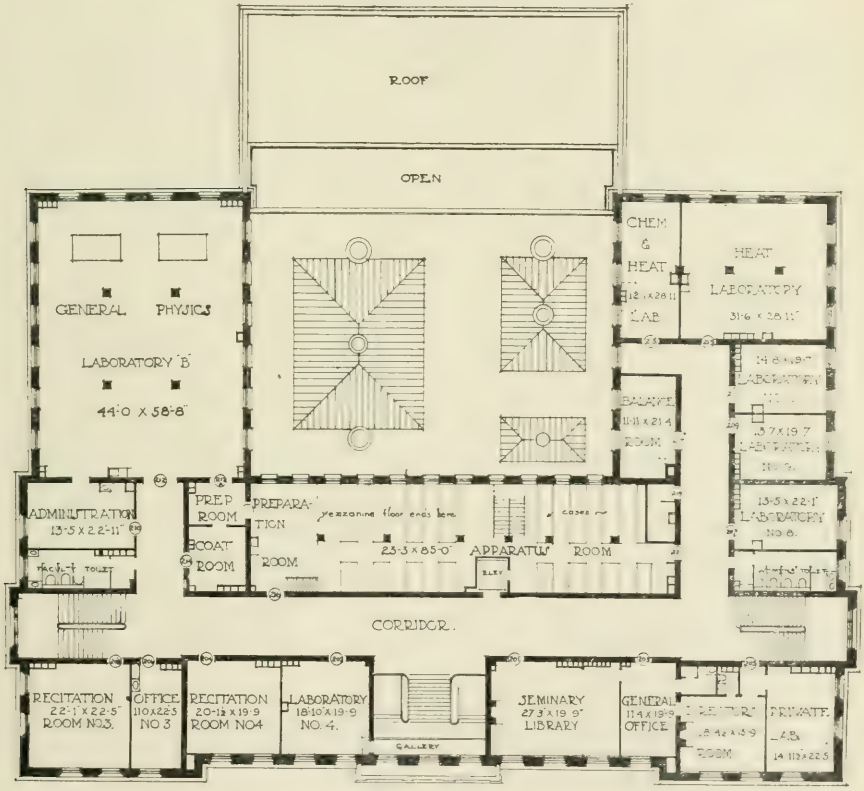


First Floor.

group of buildings in that it gives the Department of Physics a laboratory of the first rank, and also fixes a high grade for our future buildings. Only one of our previous buildings is of fire-proof construction. The burning of one of the large buildings would cripple the University work for a student generation, so that, fixing a policy of fire-proof construction is an important advance.

The site of the new laboratory, between Engineering Hall and the Natural History and Chemistry buildings, is a most convenient

one for students. For certain physical experiments, the ideal site would be a mile or more from traffic and machinery, but important conveniences for many experiments would be sacrificed in such isolation. The removal of the street car traffic from Green Street, which has been arranged by the Trustees, will take away the most serious menace to the work of the building. The walls have been made unusually heavy, many cross brick walls introduced, and a



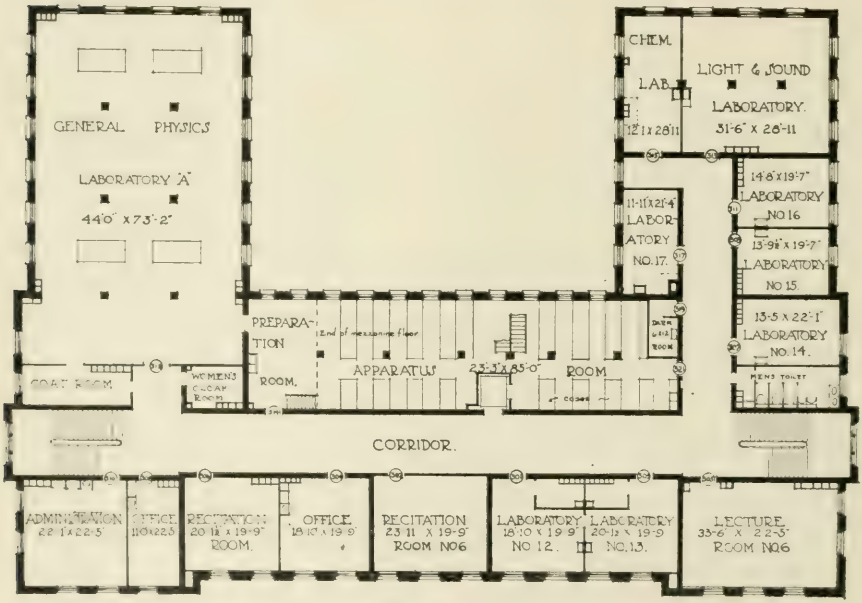
Second Floor.

series of specially designed independent instrument piers built, so that it is believed that the mechanical disturbances will not be serious.

So many physical laboratories have suffered at the hands of architects, who have sacrificed every inside convenience in order to get the architectural effects of special windows, and projecting and overhanging parts, that many professors of physics have said "in their wrath," that a physical laboratory should be of shop style and

construction. It is certainly true that the plain, square shop building would be better for the purposes of physics than some of the adaptations of cloister and gothic architecture that more than one department of physics has had to endure. But this Illinois building is evidence that a physical laboratory can be architecturally effective without sacrificing interior design. The massive building with its simple lines and effective coloring is a dignified and beautiful university building.

The chief material in the exterior walls is a local brick laid

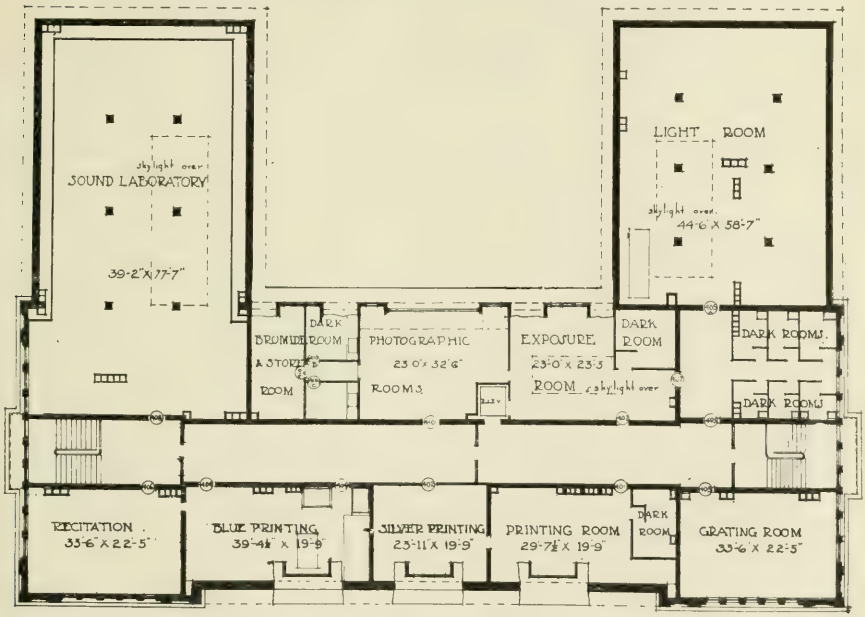


Third Floor.

in the same manner as in the Woman's Building, where the effect has proved to be exceedingly satisfactory. These brick are almost identical with the Harvard brick which are used so extensively for colonial buildings in the East, and which were first employed in the ornamental gateways at Harvard University. They are laid in Flemish bond in white mortar, with about one-third ot the headers dark, but distributed at random instead of forming a pattern. Bedford limestone has been freely used to emphasize the entrances and for the base course, belt courses, and the frieze of the cornice. It is interesting to note that two of the most expensive physical laboratories in the country, the U. S. Bureau of Standards at Washington, and the recent one at Princeton, use these same materials, name-

ly, selected red brick, trimmed with Indiana limestone. The interior walls are rough sand finished, and are to be tinted later. The doors and other mill work are of varnished red oak. The floor construction is of a standard reinforced slab type, with wooden floors on strips imbedded in concrete. The top floor is of maple. The corridors are covered with cork carpet.

The architect, Mr. W. C. Zimmerman, had free choice in the style of the exterior. In the interior, he followed with little change the floor plans which the Department of Physics worked out after a



Fourth Floor.

study of several years. In making these studies, the supervising architect, Professor J. M. White, was of great assistance in suggesting possibilities and correcting defects.

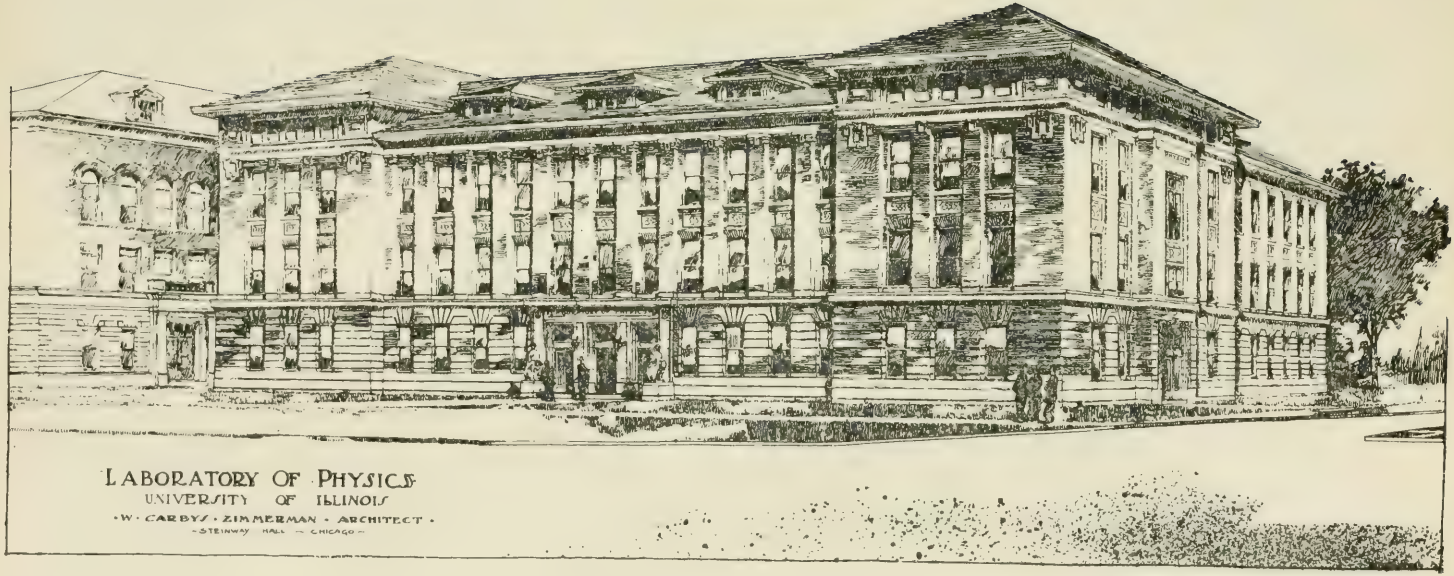
The first floor of the building is a rectangle 178 feet by 125 feet; the upper floors are U shaped. The space on the first floor between the wings is used for the two larger lecture rooms and the preparation room. These rooms are lighted from skylights. An advantage of having the lecture room on the first floor is that it reduces the climbing of stairs, quite as desirable for the quiet of the laboratory as for the convenience of the audience. This location also involves no change of floor levels in the main part of the building to obtain the height of ceiling needed for a large lecture room.

The overhead lighting is pleasant for speaker and audience, and it admits an easy and certain darkening for lantern work by a system of sliding shades operated between the glass ceiling and the skylight. An incidental advantage gained is that of an independent masonry pier at the lecture desk, thus making possible very delicate experiments in the class room. The larger lecture room has seats for 270, this number making as large an audience as is desirable for an experimental lecture. The smaller lecture room seats 120, and is for minor courses in physics.

The west wing contains three large laboratories and seven recitation rooms besides service rooms. This will confine the large classes with most of the traffic to the west side of the building, leaving the east wing largely for the advanced work of the smaller laboratories. There are 21 smaller laboratories, 3 chemical rooms, a balance room, a special lecture room seating 50, photographic and photometer rooms, even-temperature rooms, and also the usual cloak and toilet rooms. The seminary and library room is a room 27 feet by 19 feet on the second floor with three south windows. It has fixed book cases, a fireplace, and special finish and furnishings so as to make it an attractive room for reading. Provision has been made for an ample line of reference books, and also sets of the important physical journals for the last ten years. These will be duplicates so that the serials and books in the main University Library will always be available there. The seven offices face the south and have been purposely made small.

The mechanician's work shop is an annex building, this building also containing the ventilating fans. The foundations of this annex are independent of those of the main building, though the two buildings are united above by an archway with iron grille and gates. Practically all rotating power machinery is thus installed outside of the main building. The light machinery in the students' workshop on the first floor will be direct connected units. The floor of this shop is a heavy concrete slab 30 feet by 28 feet, floated independent of the walls on 18 inches of sand, so that no disturbance is expected from the occasional running of this light machinery. The elevator is of the direct-lift plunger type; this type being chosen because of safety and because it requires no rotating driving machinery. The elevator well is six feet square and extends from the unpacking room in the basement to the attic floor, with landings on the main corridor of each floor, and also on all floors of the apparatus stack.

The apparatus stack extends through three stories and has mezzanine floors after the plan of a library stack. The storage capacity is thus practically doubled and the cases are accessible without ladders. In addition to the stairway, the elevator runs up through the apparatus stack. Each laboratory is provided with one or more cabinets for apparatus in current use.



Perspective View.

The battery room is in the basement, is well lighted and has a special ventilating shaft. The storage battery has a special switchboard which is connected by a number of circuits with the central experimental switchboard. This central switchboard is also supplied with continuous, alternating, and polyphase currents from dynamos in the university power house. Two or more independent circuits of No. 8 wire run from the central switchboard to each laboratory for experimental purposes. All laboratories are supplied with gas and water, and several on each floor with compressed air and vacuum pipes. Future wiring and piping is provided for by tile ducts, which run from the basement and lead to all the laboratories. The heating is by direct radiation, with a vacuum system of piping and automatic control. The ventilation is by two fans delivering tempered air, one fan being for the two lecture rooms only. A vacuum cleaning system will be installed so as to decrease dust.

The net floor area is 20 665 sq. ft. for the first floor and shop, 16 400 sq. ft. for each of the next two floors, and nearly 7 000 sq. ft. available in the attic. Of this total area 13 000 sq. ft. is in corridors, leaving a net room area of over 47 000 sq. ft. in the building.

The University was fortunate in letting its contract at a time of lower prices, so that enough of the appropriation of $250 000.00 has been reserved to furnish and equip the building very completely. The new building gives space and facilities not only for present courses, but also for a large extension of work. The graduate work is to receive special attention. With the facilities of this building, it should become a center of physical investgation, as well as a place of instruction.

A POWER HOUSE FOUNDATION.

L. H. PROVINE, B. S.
Instructor in Architectural Engineering.

While engaged in construction work in the east, the writer had an interesting problem in foundations. The building to be built was an extension of the original Howard station of the Boston Elevated Railroad Company at Cambridge, Mass. There was the original station of 3600 K. W. total capacity, of direct connected horizontal types of engines and it was decided to build an extension with a capacity for two units of 2700 K. W. each. The present installation, however, was to be one unit, and provision for a future unit. The engine decided upon was of the vertical cross compound condensing type, of a normal rated capacity of 4100 H. P. built by McIntosh & Seymour. The total weight of the engine and generator was 550 tons. The addition comprised an engine room 66′x138′ and a boiler room 54′x186′. The site of the new building was a swamp or low-land on the Charles River, which had been filled in by the ashes from the original station. The underlying soil was of the nature of peat, which was of considerable depth. The proposition was to put in a foundation that would carry the great load of engine, boilers and necessary auxiliaries and guard against lateral vibration, also bond securely to the old foundation with its horizontal engines. An engineer's level set up on the proposed site showed a decided motion of the bubble, which was found to correspond with the strokes of the engines of the original station when running in synchronism.

The scheme as adopted was to enclose the site by a so-called cofferdam of 6″ yellow pine sheet piling driven to a depth of 40 feet. This cofferdam would tend to confine the soil within, to increase the resistance of the foundation piles and also the pressure from without would tend to resist any lateral movement.

The entire area was sheet piled and then excavation was started inside the enclosure and carried down to a depth of about nine feet below the outside grade. At this point the peat was very soft and spongy and required large spread platforms for wagons and pile drivers. Piles were driven about three feet on centers each way over the entire site except directly under the engine foundations where this spacing was changed to two feet six inches staggered. The piles averaged thirty feet in length and were cut the required length only as needed. In case any pockets at this depth were found, the piles were lengthened accordingly. The first twenty feet, a pile settled into place under the weight of the hammer. The driving from there on was not at all hard, but they were all driven

until they "fetched up" to an average of 1" penetration in five blows of a 2000 pound hammer falling eighteen feet. Several piles were tested after having been left for a day and it was found impossible to drive them further. The driving was started around the edges of the enclosure and gradually closed in to an area under the boiler room. As this area reached about twenty-five feet in diameter, a slight rise in the level of the soil was noticed and it gradually increased, as the last piles were driven they were put down with a great deal of difficulty, requiring much care in driving. The heads of the piles were then all cut off below low water level, thoroughly cleaned and were then ready to have the concrete capping. A complete pile record was kept of the entire building, giving the location, length before driving, average penetration of the last five blows of the hammer, the weight of the hammer, the fall and the length of butt cut off. This furnished an interesting record of the depth of the underlying soil.

The question of a basement under the boiler room for the handling of ashes and auxiliaries was considered, but it was decided to abandon this since the floor would be six feet below mean high water (the tide coming up the Charles River twice daily) and the cost and operation of sump pumps as well as waterproofing cement and other precautions would not justify the expense. A bed of concrete seven feet thick was placed over the entire engine room area and four feet thick over the boiler room area. On top of this concrete, in the boiler room, was placed a layer of ashes, bringing the floor up to the required grade on which a concrete floor was placed. Since the plan of a basement in the boiler room had been abandoned, the ashes from the boilers were to be raked from the ash pits and loaded into push cars running on an imbedded track, dumped into a lift in one corner of the building which carried them out of the way. On top of the seven feet of concrete, a foundation of concrete for the engine was carried fourteen feet higher.

The old foundation under the original power station was bonded to the new foundation by means of twisted rods and old rails which had been thoroughly cleaned. The solution of this foundation problem seemed to result as expected. After the new foundation was completed, there was no perceptible vibration, although at the far end of the old station the vibration was still evident.

A new brick chimney two hundred twenty-five feet high was also built. The brick work was carried on an octagonal footing of concrete thirteen feet thick, which in turn was carried on a pile foundation driven to safe bearing. The chimney area was enclosed by sheet piling similar to the new building.

MAKING CONCRETE WATERPROOF.

Ira O. Baker, C. E., D. Eng'g.
Professor of Civil Engineering.

Concrete is very largely employed in many building constructions, and in some situations it is very important that it should be at least practically waterproof. There are several methods of rendering concrete more or less impermeable to water, some of which are simple and free to any one, and some of which consist in using secret or patented compounds. Of the former the simplest method consists in mixing hydrated lime or finely divided clay with the concrete, thus at least partially filing the voids or interstices in the concrete and decreasing the percolation of water. Another simple method consists in mixing powdered alum with the cement and dissolving ordinary soap in the water to be used in mixing the concrete. Although the latter materials have been used for more than sixty years as a wash for rendering masonry impervious to water, and although in recent years they have frequently been employed as ingredients of concrete to make the entire mass impermeable, the proportions to be employed and the reason for the effect seems to have had little or no scientific consideration, at least the proportions used in practice vary very widely. For the purpose of securing data for use in the revised edition of the writer's Treatise on Masonry Construction, now in preparation, certain investigations and experiments have been made; and it is the object of this article to present these results more fully than can be done in the book mentioned.

Alum and Soap Waterproofing Compound.

To use the alum and soap method of decreasing the permeability of mortar or concrete, the alum in powdered form may be mixed with the dry cement or the sand, and the soap may be dissolved in the water employed in mixing the concrete; or both the alum and the soap may be dissolved in the water. The former is probably the safer method in practice, since with the latter method the water must be thoroughly stirred while the two are being mixed or the precipitate may form in large masses which it is practically impossible to break up; and further the water must be kept stirred to prevent the compound from accumulating on the surface. These are conditions that it is not always easy to be certain of securing. However, the alum is more easily dissolved than the soap; and hence the alum may be dissolved in, say, one fifth of the water and the soap in the remaining four fifths, and then the two portions may be mixed together, being careful to stir them as the mixing progresses. The

alum and the soap combine and form a finely-divided, flocculent, insoluble, water-repelling compound which fills the pores of the concrete and decreases its permeability.

The best proportions are: alum 1 part and hard soap 2 parts, both by weight. Soap varies in its chemical composition, and hence a single proportion can not be stated which will be chemically exact for all cases. The above proportion is in round numbers the relative combining weights of alum and average hard soap; and hence it is the best proportion to use, although widely different proportions have been used in practice with success. Any reasonably pure soap will do; but if soft soap is employed, a greater amount should be used in proportion to the amount of water in it.

It is difficult to dissolve more than about 3 per cent. of hard soap in cold water; and hence this practically limits the amount of alum to 1.5 per cent. and of the soap to 3 per cent. These amounts will give a precipitate equal to about 3 per cent. of the weight of the total water. The amount of precipitate formed in the pores of the mortar or concrete will depend upon the amount of water used in the mixing. Of course, if it were desired to use a greater quantity of soap and alum, the soap could be first dissolved in a smaller quantity of hot water, which is afterwards mixed with the water used in making the mortar; but this is hardly practicable, nor necessary, as will appear presently.

An excess of alum does no harm, since alum alone is a fair waterproofing material. An excess of soap does no harm; and an excess is better than a deficiency, since the excess will unite with the free lime of the cement and form calcium soap—a finely-divided, water-repelling compound which is apparently the essential element of several of the proprietary waterproofing compounds. The above is the explanation why such diverse proportions of alum and soap give reasonably successful results in actual practice.

EFFECT OF WATER-REPELLING COMPOUND.

A film of oil on the wires of a moderately fine sieve makes it nearly, if not quite, water-tight. The question then naturally occurs: Can a water-repelling compound in the concrete act in the same way as oil on a sieve? Or in other words, can a volume of water-repelling compound less than the volume of the voids in the concrete decrease the permeability of the concrete in a greater ratio than the per cent. of the voids filled? If so, then a water-repelling compound is more efficient in decreasing the permeability of a concrete than a mere void-filling material.

To test the effect of a water-repelling ingredient upon the permeability of concrete, a series of experiments were made under the writer's direction by Mr. B. L. Bowling in the cement laboratory of the University of Illinois. The experiments consisted in moulding

a series of Portland-cement mortar disks in short lengths of 6-inch pipe, subjecting these disks to water under pressure, and measuring the amount of percolation. For convenience in making the experiments, mortar was used instead of concrete. The mortar for the treated and the untreated disks was alike except for the alum and soap compound. However, the mortars containing the alum and the soap were invariably drier than those made without these ingredients; but this probably has no significance in this connection. An inch annulus at the circumference of both the top and the bottom faces of the disk was coated with hot asphalt, and also covered with a rubber gasket against which a flat casting was pressed by bolts through an external flange; and consequently the flow was through a disk 4 inches in diameter and 2 inches thick. The percolating water was caught in a tin funnel, the top of which fitted closely against the lower casting and the neck of which passed through a perforated rubber stopper into a bottle. The water pressure varied from 40 to 45 pounds per square inch. The date and the results of the experiments are given in the table on page 52. Tests 1 and 2 were made together, as also tests 3 to 6, and 7 to 9. The intention was to have four tests in each series, but through one reason or another some of the tests were of doubtful value or were useless, and hence are not reported.

The mortar used in making the disks was 1:6, which is unusually lean and porous. but it was purposely made porous the better to test the effect of the alum and soap compound. Known weights of cement, sand, and water were used, and the volume of the mortar produced was measured; and then knowing the specific gravity of the several ingredients, the density of the resulting mortar was computed by a process not necessary to explain here. The voids in each disk are stated in the table, and ranged between 23.4 and 24.0 per cent. If the sand had not been well-graded, the per cent. of voids would have been considerably greater, and also the individual voids would have been larger. A 1:2:4 concrete made of well-graded sand and stone would have only about 12 to 15 per cent. of voids.

The amount of water used in making each of the several disks is stated in the table on page 52. Knowing the per cent. of alum and soap in the water and the amount of water used in mixing, it is easy to compute the amount of the precipitate in the mortar. The amount of precipitate in each disk is given in the table.

The percolation for each of several successive 24-hour periods is given in the table. The results show that the alum and soap precipitate is quite effective in decreasing the percolation. In the first series of experiments, No. 1 and 2, the alum and soap compound equal to 1.2 per cent. of the cement stopped a little over 76 per cent. of the porcolation during the first 24 hours; and the corresponding results for the other series are 54 and 69 per cent., respectively. The

EFFECT OF ALUM AND SOAP ON PERMEABILITY OF CEMENT MORTAR.

Test No.	Water Per cent. of Dry Mat.	Precipitation		Percolation, in Grains per 24 Hours													
		Per cent. of Cement	Per cent. of Voids	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	10	0	23.4	945	155	94	61	51	34	30	26	18	14	14	12		
2	10	1.2	23.6	224	37	21	12	10	6	5	4	2	2	2	2	12 2	6 2
3	12	0	23.9	1113.0	342.3	195.0	166.6	132.7	120.4	98.0	73.5	61.4	55.5	52.8	44.9		
4	12	0	23.9	1061.2	330.6	178.4	145.0	123.2	107.7	66.3	49.8	41.1	37.6	36.3	30.6		
		mean		1087.1	336.4	186.7	155.8	127.9	114.0	82.1	61.6	51.2	46.5	44.5	37.7		
5	12	1.4	24.0	497.8	206.8	122.3	76.7	64.2	58.2	36.0	25.0	21.0	19.5	17.0	15.0		
6	12	1.4	24.0	517.0	222.2	132.2	87.7	72.1	65.1	39.4	26.1	21.7	19.5	16.9	16.2		
		mean		507.4	214.5	127.2	52.2	68.1	61.6	37.7	25.5	21.3	19.5	16.9	15.6		
7	12	0	23.9	1101.1	324.0	150.9	108.4	84.8	79.2	56.6	59.1	48.9	35.5	31.0	29.2	47.3	21.5
8	12	2.8	24.0	339.5	221.2	114.8	75.2	54.4	50.4	33.3	33.7	28.0	20.2	17.3	16.0	25.5	11.0
9	12	2.8	24.0	333.8	213.4	113.6	74.9	52.2	47.6	31.5	32.0	25.4	18.0	16.3	14.3	22.3	10.2
		mean		336.6	217.3	114.2	75.0	53.3	49.0	32.4	32.8	26.7	19.1	16.8	15.1	23.9	10.6

variation in the several series is surprisingly large, but it is certain that the experiments were carefully made; and the range in the results probably indicates the effect of undetected inequalities in the materials, the proportions, and the mixing.

Somewhat similar results were obtained for each of the successive 24-hour periods. The decrease in percolation through the treated and also through the untreated disks is due to two causes, viz.: 1. The percolating water doubtless has in it some solid matter, which clogs the pores of the upper surface of the disk. However, the water employed was that in the city water mains and was reasonably free from solids. 2. The percolating water takes up the soluble portions of the mortar from the upper part of the disk and carries them to the lower part. It is universal experience that all masonry becomes more nearly water-tight after use. It is interesting to note that in this series of experiments the average percolation during the twelfth 24-hour period was only 2.6 per cent. of that during the first period.

The most interesting feature of these experiments is that the alum and soap compound equal to an average of 1.2 per cent. of the cement in a mortar containing an average of 23.7 per cent. voids, stopped 65 per cent. of the percolation; or, in other words, adding water-repelling void-filling material equal to approximately 5 per cent. of the voids reduced the percolation to one-third of that of untreated mortar. One can hardly conceive that an equal amount of a non-repelling void-filling material would be equally effective. Apparently then the alum and soap compound in the concrete acts like oil on the wires of a sieve. The experiments are being continued to determine the effect of the alum and soap compound with less-porous mortars.

The mixing of alum and soap in the concrete reduces its strength somewhat; but there are many situations in which strength is unimportant, or at least is less important than water-tightness. The effect of the alum and soap upon the strength of the mortar varies a little with the method of storing the test samples. For example, the mean of six neat Portland cement briquettes mixed with 21 per cent. of water which contained ½ of 1 per cent. of alum and 1½ per cent. of new "Ivory" soap, when left in the molds 1 day and stored in a moist chamber for 6 days, had a strength of 87 per cent. of that of similar briquettes made with water alone; and when left in the moulds one day and then stored 6 days in water had 84 per cent.; and when twice as much alum and soap were used, the strength was 83 and 71 per cent. respectively.

A BETTER WATER-REPELLING COMPOUND.

Instead of using alum and soap as above, it is better to substitute aluminium sulphate (sometimes, but improperly, called alum) for the alum. The aluminium sulphate is cheaper than alum, and only about two thirds as much of it is required; and the compound formed is equally water-repelling. The best proportion, in round numbers, is: 1 part of aluminium sulphate to 3 parts of hard soap, both by weight. Aluminium sulphate equal to 1 per cent. of the water and hard soap equal to 3 per cent. of water will give a dry precipitate equal to 2.5 per cent. of the water.

As with the alum and the soap, an excess of either of these ingredients does no harm; but an excess of soap is better than an excess of aluminium sulphate, since the soap unites with any free lime in the cement and forms calcium soap, which is a better waterproofing material than the aluminium sulphate alone.

Apparently no attention, except possibly by the manufacturers of proprietary waterproof compounds, has been given to the relative effect of capilliary repellent and capilliary attractive compounds.

One of the best means of making mortar or concrete waterproof is to make a dense mixture, i. e., to use plenty of cement and well-graded sand and broken stone; but nevertheless there are circumstances in which it is desirable to use a waterproof wash or to make a moderately lean mixture impermeable by adding a waterproofing ingredient to the mortar or the concrete. Either pair of the above ingredients is excellent when used as a wash to make a wall waterproof, as for example a cistern. To use them for this purpose, make solutions of the alum or the aluminium sulphate and of the soap of the proportions stated above; and then apply one of the solutions to the wall, and when it has dried apply the other. Apply as many pairs of coatings as may be necessary, which will usually be only two or three. It is better to apply the solutions hot; and it is important that they should be well rubbed on, but it is vital that they shall not be rubbed to form a froth.

REVIEW OF METHODS OF WATERPROOFING CONCRETE STRUCTURES.

C. G. DERICK, S. B.
Assistant in Organic Chemistry.

The rapid development in the use of cement plasters and concrete for construction purposes has brought forth many new problems for solution. Perhaps one of the most important has been that of constructing water-proof structures, that is, structures which are proof from percolating water as well as from dampness. Yet in another light, this problem of water-proof construction applies equally well to the use of building materials other than cement.

The reasons for water-proof construction are many, and differ with the locality. In general it is very desirable to make reservoir dams of material impervious to water. Along the sea-coast the problem becomes very acute. Cellars to our modern business blocks are sunk far below the high tide mark and in certain cases under the writer's observation, sub-basements were subjected at high tide to the pressure of 18 feet of water. But such basements are of great value for storage and must be water-proof. Again in certain places water and sewage mains must run in parallel and it is of the greatest importance that no contamination of the water supply should be possible. But perhaps the greatest argument for water-proof construction is durability and permanency. The reinforcing, which makes the extended use of cement concrete possible, must remain intact. But many observations have shown that this is not the case where the concrete is pervious to water and exposed to the action of chemicals in solution in the water. From this view point water-proofing is very necessary to prevent the disintegration of reinforcing as well as the cement itself.

To construct water-proof structures for one or more of the above reasons has long been the task of the engineer. A question much discussed is whether or not it is possible to construct buildings from cement concrete alone which shall be water-proof. Beyond a doubt this is possible, for a carefully applied cement plaster lining of foundation walls has in many cases rendered these walls impervious to water. But such work requires special materials and workmanship. The sand and stone must be carefully graded and applied with the greatest care. A member of a prominent New England firm summing up the whole matter stated that it is not a question as to whether or not cement concrete may be made water-proof by the careful gradation of materials in the hand of expert men, but that with the ordinary type of unskilled labor employed

water-proof construction is impossible. This statement was made in spite of the fact that his company held the record for the construction of water-proof structures in that neighborhood. Further, he stated that anything which could be added to the concrete to insure its being water-proof without greatly increasing its cost was to be desired and had an almost unlimited application.

It is a well known fact that alum and soap mixtures have been used for water-proofing since the middle of the last century. Very probably at first they were used as external washes, but more recently they have been applied to concrete itself, by means of the water used in the mix. Various proportions of alum and soap have been recommended, but in every case there is a distinct lack of cleanness about each procedure, caused apparently by a lack of the knowledge as to how the water-proofing effect is brought about. The water-proofing effect is due to the precipitation of the insoluble aluminium salts of the organic acids occuring in soap. These salts partially fill the pores of the concrete and give the finished concrete a repellent action toward water. Hence it is evident that the alum and soap should be used in the exact proportion demanded by the chemical equation. But to determine this proportion the analysis of the soap must be known as well as the composition of the alum. Moreover the best practice today recommends that the amount of alum and soap precipitated into the concrete should equal but not greatly exceed 2% of the neat cement used in the ordinary mix for concrete. But the use of alum is needlessly expensive. Alum has the formula $K_2SO_4, Al_2(SO_4)_3, 24H_2O$ in which the desired material, aluminium sulphate, $Al_2(SO_4)_3$ makes up only 36% of the whole. It would be far better to use alum sulphate, which as a commercial product has the formula $Al_2(SO_4)_3\ 18H_2O$ in which there is 51% of the desired $Al_2(SO_4)_3$. Even with this modification the method is much more expensive than many others which give just as good results.

Until very recently the use of the tar and felt seal method for water-proofing buildings has had universal application. It can be applied to structures built of any ordinary building material and if successfully applied gives very satisfactory results. This seal is applied by two different methods. First, it may be applied to the outer surfaces of the foundation walls and floor. Second, it may be applied to the inner surfaces of the same.

One method of applying this seal to the outer surfaces of walls and floor consists, in brief, in first building a small retaining wall of some cheap material which will support the seal until the real foundations are put in place, as well as to protect it from the outside wear. This retaining wall is mopped with tar, to which is applied tar paper which is then carefully mopped with hot tar to seal all joints. Several successive layers of paper and tar are applied according to the specifications. Great care is taken, or should be,

to insure each layer's being water-proof before the next is applied. When the seal is completed the foundation walls are built snug against it. The seal makes a complete water-proof shell within which the foundation walls and floor rest.

In the second method, the shell is constructed within the finished structure. To protect it and hold it in place a retaining wall is built within the foundation walls and this retaining wall varies in thickness according to the external water pressure.

Practice differs as to which method shall be employed, but many firms desire to apply the seal to the inner surface of the foundations as given in the second method, the reasons for which will appear presently. With the first method careful over-seeing is necessary to prevent the seal from being punctured while the foundation walls are being built, for often one firm applies the seal and another puts in the foundations. If the seal is punctured, it is very difficult to fix the responsibility, and this is one reason why the seal method is undesirable. The strongest argument against the use of the seal is the difficulty of patching it after the structure is completed and the seal becomes punctured. A break in the seal is made evident by a damp spot on the wall, or, often, percolating water. At this point the walls are torn away to expose the seal; but as often happens the puncture is not at this point—so the wall must be removed until the leak is found. It is very evident that this process is much simpler in the second case where the shell is within the foundation's walls and supported by a thin retaining wall. In either case the cost of repairing the seal is very great and the uncertainty of quickly locating the leak makes the method undesirable. In one case, where the writer was called in to assist after three weeks of steady searching the leak was found. In another case—that of the Shawmut Bank building in Boston—where the seal was applied to the outer surface of the foundations—the writer found the only way to make the completed structure water-proof was to apply a patent water-proof cement coating to the inner surface of the brick walls of the entire cellar. The objections to the use of the second method of applying the seal are that much valuable storage space is taken up by the retaining walls and that the reinforcing in the foundation walls is exposed to the action of the ground water.

The result of the general dissatisfaction with the seal method has resulted in the discovery of many new methods of water-proofing and today there exist several firms making chemicals which, when applied to the cement, will insure its imperviousness to water. The present methods are very different but fall into two general groups, namely, those that are applied as external washes or paints and those that are incorporated into the cement during the mixing.

Under the first division, the use of alum and soap washes, cement grout, finely suspended slaked lime or magnesium carbonate,

asphalt paints and inferior coatings of tar or asphalt are the most important. In the cases where the external pressure due to the water is small these methods will give more or less water-proof structures, but in every case they are exposed to wear and soon become punctured. Here again the reinforcing is exposed to the action of the ground waters which seep through the concrete.

The modern water-proofing that is giving the most satisfactory results is that in which the water-proofing material is made a constituent part of the concrete. Such material must be insoluble in water and possess permanency toward heat, atmospheric conditions, and the substances carried in solution in the ground water,—weak organic acids, alkalies, etc. Moreover they must have a harmless action upon the concrete itself, that is, they must not decrease its temporary or permanent strength. With these qualifications in mind the problem becomes much restricted for the chemist, and the result has been several very successful methods of rendering the concrete, within itself, impervious to water.

This type of water-proofing is accomplished by three different general methods. By the first the foreign material may be added to the concrete by means of the water used in the mix, either as a true solution or as a suspension. In such cases where the water-proofing material is added as a true solution, the chemicals must react with each other or with chemicals in the cement to produce the desired insoluble water-proofing compounds. Few processes of this type are now employed and they are trade secrets. One firm, which well illustrates the recent development in this type of water-proofing, first used a true solution, next employed a treated cement and at present use a prepared cement ready for application as a plaster, which consists of cement, sand and water-proofing compounds. Many reasons may be advanced for this development, namely, secrecy, insurance of equal distribution of water-proofing compounds, and profits upon the cement, sand and chemicals.

Under the second subdivision of this first general method, the alum and soap mixtures are representative examples. But the use of lime and soap mixtures is by far the cheaper and of exactly the same water-proofing value. The product formed by these mixtures is a calcium soap, which is insoluble in water and very stable under ordinary conditions. But if used in a boiler room it must be protected by a considerable thickness of concrete where it underlies the fire box. Ordinary insulated steam pipes do not affect these soaps. Very recently, experiments have shown that colloidal clay may be used as a water-proofer with excellent results. Yet many tempting dangers follow in its course, since it offers a great incentive to fraudulent cement making. Moreover it is not always accessible and unskilled labor is hardly to be trusted with its use.

In the second general method, the foreign material is added to

the neat cement by means of organic solvents. The water-proofing materials are in general paraffine, stearic acid, and waxes. A solution of these in benzine is applied to the neat cement and the organic solvent evaporated while the cement is agitated to insure equal distribution of the water-proofer. It is very evident that this method is costly because of the materials and special apparatus needed and it can never hope to compete with the calcium soap method.

Lastly, in the third general method, the water-proofing material is added by mechanical mixing of the foreign matreial and the neat cement, of the foreign material, neat cement and sand, or of the foreign material, neat cement, sand and stone. By whatever process employed, its success as a water-proofer depends upon its thorough and equal distribution throughout the concrete so as to render each part of the finished structure equally impervious to water. The literature upon this subject very early noted the use of mixtures of slaked lime and waxes, which were ground with the neat cement, the idea being, that in the presence of water, insoluble calcium salts of organic acids would be precipitated within the concrete. Such a method introduces needless materials of excessive cost. In the place of lime and waxes should be added calcium soaps which are a commercial product and very cheap. Many trade products such as the Medusa water-proofing compound are undoubtedly nothing but the lime salts of certain organic acids or their equivalents. For a detailed description of these compounds and their use, the prospectus put out by the Medusa Water-proofing Company will suffice.

The writer has experimented with each of the foregoing clasess of compounds used to make cement impervious to water. The substances used being paraffine, beeswax, carnauba wax, spermaceti, linseed oil and salts of organic acids which were applied according to some of the above mentioned methods. A qualitative test adopted to show the presence of water-proofing characteristics consisted in making small cup-like pieces of cement plaster treated by each of the above chemicals. These moulds were filled with water, after having thoroughly set, and if the chemicals gave the cement plaster water-proofing characteristics of any value no percolation or dampness should appear on the bottom of the moulds no matter how long the water remained in them. In general a 1:1 or 1:2 mix with a good sharp sand was used in making the moulds. Moulds containing the following percentages of water-proofing compounds were used: 1-100, 1-10, 1-2, 1, 2, and 5. In every case marked water-proofing qualities were noted even with the percentage of material as low as 1-100%, but more satisfactory results were obtained only when the water-proofing material ranged from 1-2 to 2% of the neat cement employed. In every case, 5% of foreign material destroyed the strength of the plaster while 2% or under apparently

made no difference in the tensile strength tests. The presence of the water-proofing material had a marked effect on the rate of the preliminary hardening which was always checked. Of all the chemicals used, the lime soaps appeared the most desirable and with these quantitative tests were made. The first test was to patch a leaking brick wall which had been previously coated with a plaster of a water-proof cement. After checking the flow of water, the leaks were coated with the treated cement containing 1% of lime soap using a 1:1 mix. After successfully completing this test, the original concrete on a piece of new construction was treated with the same chemicals. The result was a water-proof structure quite impervious to the external water pressure of eight feet. Further this test showed that concrete may be more easily water-proofed than cement plaster and that it requires no greater percentage of water proofing materials.

The question now naturally arises as to how such water-proofing is brought about. To this question no correct answer can be given at present. However, it is evident that the small percentage of foreign material added to the concrete does not fill the voids in the same, completely nor to any appreciable extent. Yet one characteristic of water-proofed concrete is very evident. The capillarity, which causes the water quickly to creep over and through ordinary concrete is destroyed in the case of the water-proofed product. In this direction, the cause of water-proofing may find its ultimate explanation.

STEAM TURBINE PERFORMANCE.*

J. C. THORPE, M. E.
Assistant Professor of Steam Engineering.

A consideration of some particular installations with the results of steam economy tests will indicate the measure of success that has attended the recent development of steam turbine practice.

In 1902, after very careful consideration of the steam turbine problem, the Commonwealth Electric Company, of Chicago, purchased the first 5000 Kw. machine that was built. Just previous to this the Westinghouse Company had taken the contract to build a 1500 Kw. unit which was installed in the plant of the Hartford Electric Light Company, of Hartford, Connecticut. It is worthy to note that this turbine, Unit No. 1 in the Fisk Street Station of the Commonwealth Edison Company, was the result of the first effort that had ever been made in this country to build a machine of this type larger than 600 Kw. The 600 Kw. turbine mentioned was a two stage, horizontal Curtis machine installed in 1901 in the shops of the General Electric Company at Schenectady, New York. It is a compliment to the engineers and management of the General Electric Company who built and installed this first larger unit, that they planned and built so well and confidently at that time. We doubt not that, in the light of more recent designs, this first large turbine to be installed in this country fails to nourish the pride of its designer, and yet, all must agree that the undertaking at that time was very meritorious.

The writer has been privileged during the past three years to conduct tests on three of the units in the Commonwealth Electric Company's station. These units with the approximate dates of installation and their respective Kw. ratings are as follows:

Unit No. 1, first operated September, 1902, normal capacity 5000 Kw.

Unit No. 4, first operated September, 1905, normal capacity, 5000 Kw.

Unit No. 8, first operated December, 1906, normal capacity, 8000 Kw.

*Extracted from paper presented before the Western Society of Engineers, May 5, 1908.

A brief summary of the results of these tests is presented in the following table:

TABLE NO. 1.

OPERATING CONDITIONS.

Comparative Results—Best Performance.

		Unit No. 1	Unit No. 4	Unit No. 8
1.	Nominal Rating of machine Kws.....	5000	5000	8000
2.	Load—Gross output Kws.....	6137	5970	10156
3.	Ditto—per cent normal rating.....	1.25	1.20	1.25
4.	Water rate—observed—K.W.H.....	23.85	16.56	12.94
5.	Ditto—corrected for "contract conditions"	23.94	16.72	13.07
6.	Water rate—observed—E.H.P.H.....	17.89	12.42	9.71
7.	Ditto—corrected for "contract conditions"	17.96	12.54	9.80
8.	Initial Pressure	176.6	174.0	176.0
9.	Vacuum observed	28.10	28.0	29.17
10.	Vacuum 30" Barometer	28.52	28.30	29.50
11.	Superheat—Deg. Fahr.	139.0	184.0	147.0
12.	First stage pressure, Lb. Gage.....	5.66	34.8	46.7
13.	Normal speed, R. P. M.....	500	500	750

NOTE:

1. A considerable condenser leakage necessitated a correction in the steam flow of Turbine No. 1.

2. Results of tests of No. 4 taken from Report of Tests of Turbine No. 4, J. C. Thorpe to Mr. F. Sargent, April 24, 1906.

The accompanying curves, Figure 1, present the relative steam economies of these three units in a very interesting manner. It will be seen that the scale of the vertical ordinate, representing water rate, is continuous, thus giving a direct comparison of the units, all values of the steam economy having been reduced to the basis indicated. Another notable feature is the flatness of the load curve for Unit No. 8. It is noticeable in No. 4, but less markedly and the tendency to give a wide range of economy with a considerable range of load is hardly perceptible in the first unit. It is difficult to say what the results would have been in the latter case had the load been increased to 75% overload, as in the case of No. 8. These curves serve better than words to illustrate the remarkable development in the design and operation of large turbine units of this type during the past five years.

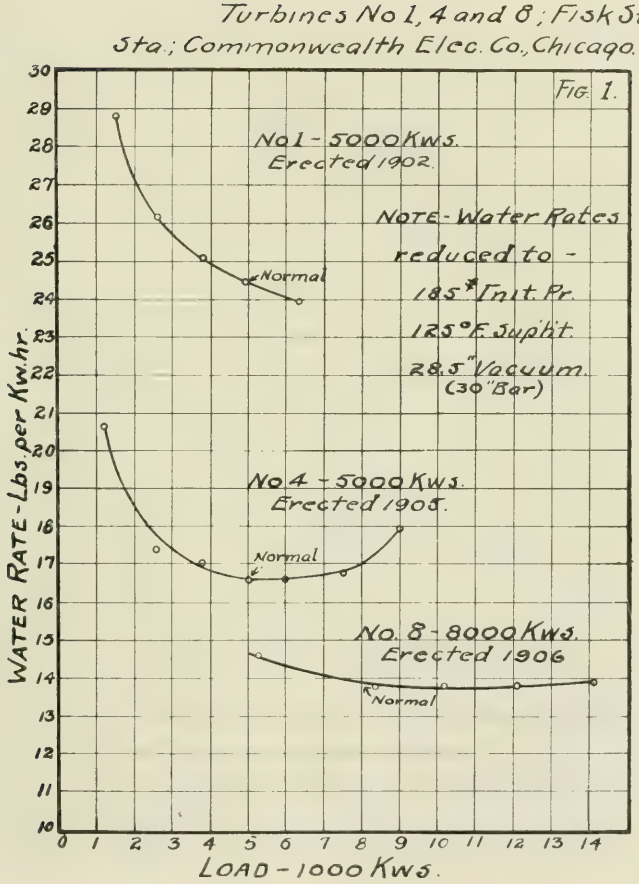

Turbines No 1, 4 and 8; Fisk St. Sta.; Commonwealth Elec. Co., Chicago.
Fig. 1.
No 1 - 5000 Kws. Erected 1902.
Note - Water Rates reduced to - 185# Init. Pr. 125° F. Sup'ht. 28.5" Vacuum. (30" Bar)
Normal
No 4 - 5000 Kws. Erected 1905.
Normal
No. 8 - 8000 Kws. Erected 1906
Normal
WATER RATE - Lbs. per Kw.hr.
LOAD - 1000 Kws.

Fig. 1. Relative Steam Economy.

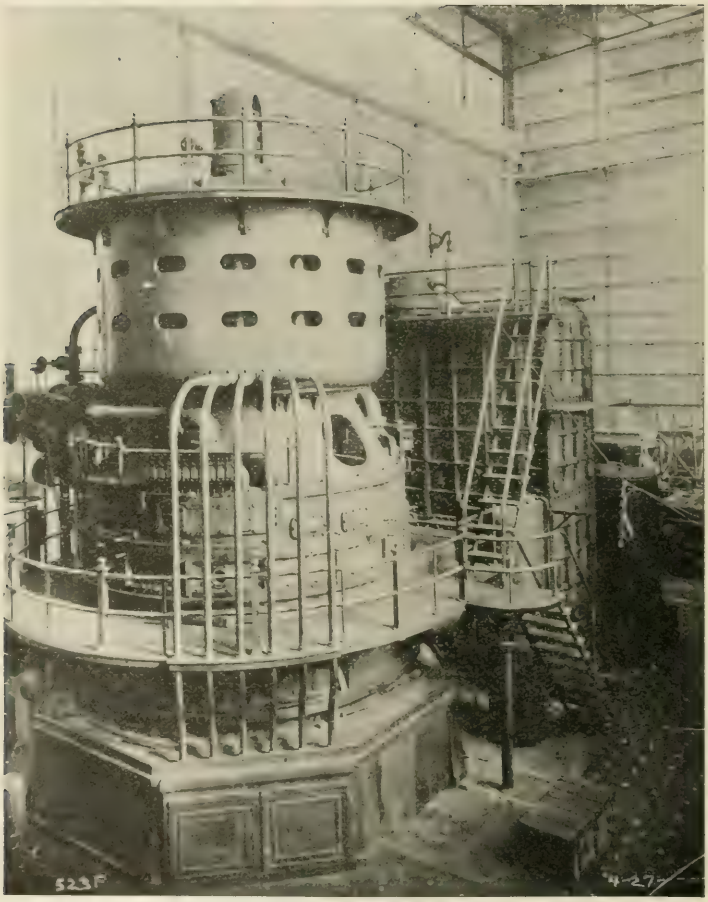


Fig. 2. Unit No. 1. Curtis Steam Turbine Unit. Capacity 5000 Kw.

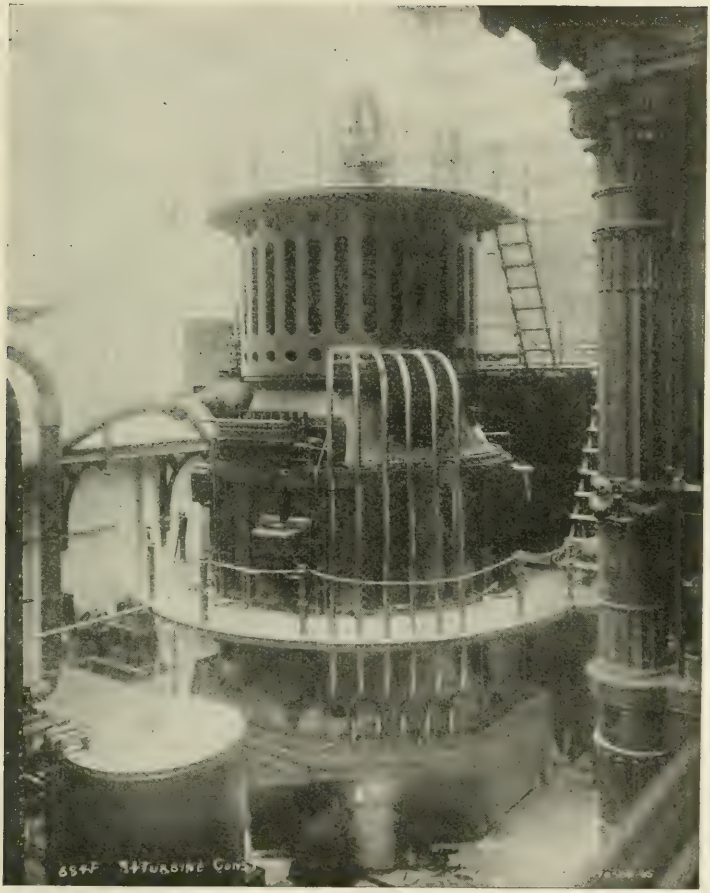


Fig. 3. Unit No. 4. Curtis Steam Turbine Unit. Capacity 8000 Kw.

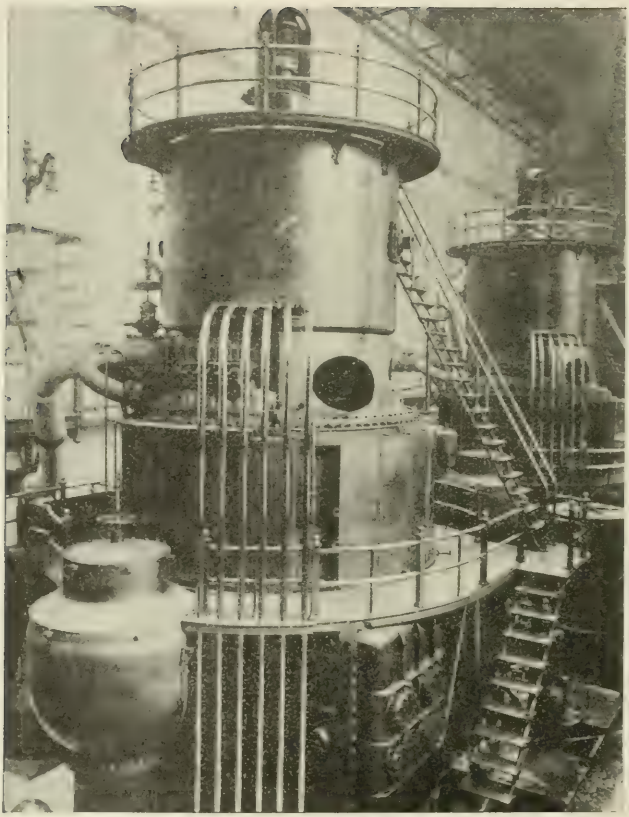


Fig. 4. Unit No. 8. Curtis Steam Turbine Unit. Capacity 8000 Kw.

Figures 2, 3 and 4 represent the three units as they appear in the Fisk Street Station.

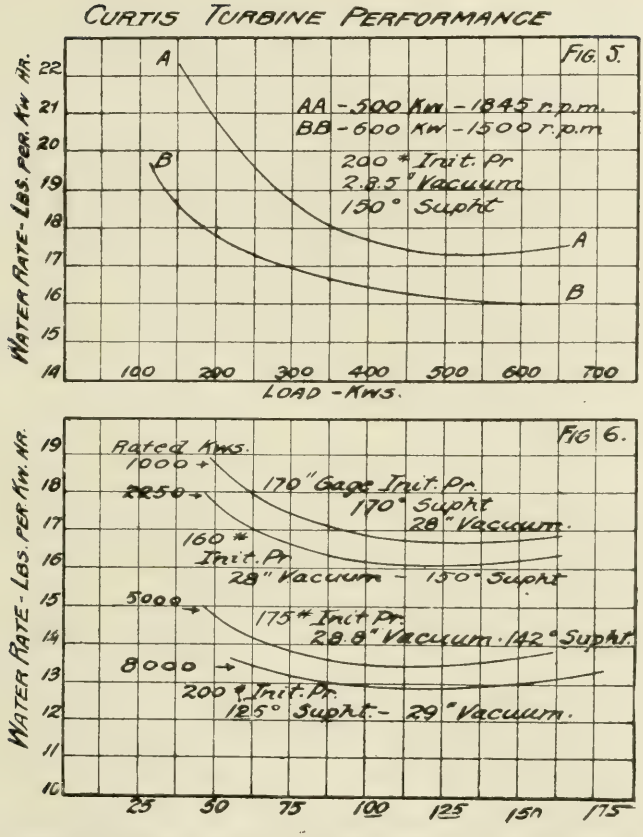


Fig. 5. Relative Steam Economy of Two Early Curtis Turbines; Reduced To Same Conditions.

Fig. 6. Relative Steam Economy of Four Curtis Turbines; Not Reduced To Same Conditions.

The curve BB in Figure 5 represents the steam economy of the 600 Kw. horizontal Curtis turbine mentioned above, and curve BB, the economy of a 500 Kw. Curtis turbine, erected in the station of the Massachusetts Electric Company at Newport, Rhode Island. The test was conducted by George H. Barrus and appears in a bulletin issued by the General Electric Company. The difference in water rate is probably due to the fact that the 500 Kw. machine was tested with a service load which fluctuated greatly during each trial; whereas, the test of the 600 Kw. machine was a shop test when more nearly absolute control was had over all of the conditions affecting performance. It might be assumed that the development of

four years should result in increased economy. This is not necessarily true, particularly with the smaller units, since the requirements of the service may necessitate mechanical changes whose desirability outweigh the relative importance of an inconsiderable increase in steam economy.

Figure 6 presents the load curves of four Curtis turbines of 1,000, 2,250, 5,000 and 8,000 Kws. rated normal capacity. In this instance the conditions of operation are not reduced to a common basis, but appear as actually observed. An inspection of the values given will indicate that no considerable change would result if a reduction had been made as in Figure 1. The curve in Figure 7 was constructed from Figure 6, using the steam economy for the points of normal loading and all reduced to a common basis, namely, 185 pounds (gage) initial pressure, 28.5 inches vacuum, (30 inches Bar.) and 150° Fahrenheit superheat. This curve illustrates the well-known fact that the ratio of the energy losses to normal capacity decreases with the increasing size of units, just as the same ratio varies with the load on a given unit.

Corrections on these curves were based upon the following values, derived from actual tests, when all the conditions of operation, except those under trial, were maintained as nearly constant as practicable:

1 inch vacuum between 26 inches and 30 inches = 5% effect upon water rate.

14° Fahrenheit superheat, = 1% effect upon water rate.

10 Pounds Boiler Pressure between 150 and 185 = ½% effect upon water rate.

Difference between 185 and 200 pounds boiler pressure = negligible.

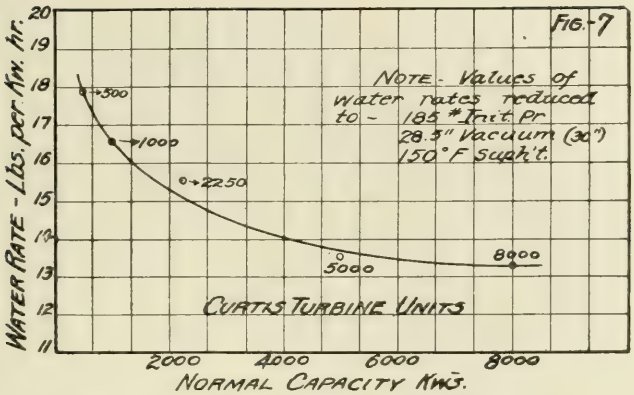
In the Electrical World of October 12, 1907, the following corrections for departure from contract conditions during a test of a 7500 Kw. Westinghouse-Parsons turbine in the plant of the New York Edison Company, are recorded:

Pressure—2½ pounds high = corrections, .25% in water rate.

Vacuum, .69 inches low = correction, 1.84% in water rate.

Superheat, 4.25° low = correction .29% in water rate.

It will be noticed that the influence of the variation in steam pressure is apparently much greater with the Parsons type of machine and the influence of variations in vacua much less, than in the performance of the Curtis type. There is practically no difference in the allowance made for superheat. It appears upon careful consideration that the turbine which governs by virtual throttling, would not be improved to any considerable degree by increases in pressure. Furthermore, the influence of vacua might be expected



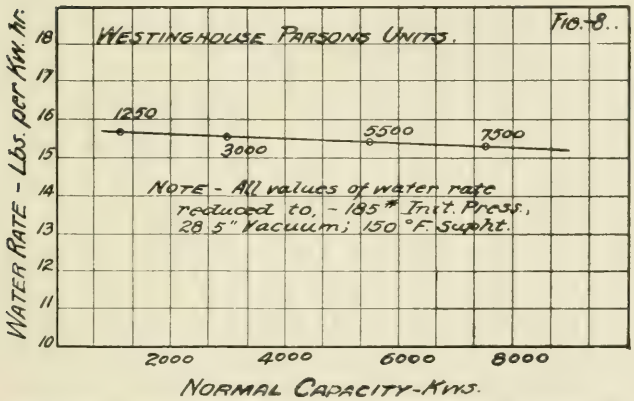


Fig. 7. Relative Steam Economy of Four Curtis Units of Fig. 6, Reduced to Same Conditions.

Fig. 8. Relative Steam Economy of Five Westinghouse-Parsons Units of Fig. 9, Reduced to Same Conditions as Fig. 7.

to be much greater than stated, concluding from experience with other machines.

Figure 8 presents the relation of water rate of various Westinghouse-Parsons turbine units, plotted upon the same basis as the curve in Figure 7. The actual load curves from which this curve is obtained appear in Figure 9. A marked contrast between Figure 7 and Figure 8 is immediately noted; a difference in water rate of $3\frac{1}{2}$ pounds existing between the 1,000 and the 8,000 Kw. units of the Curtis pattern, and but $\frac{1}{2}$ pound difference over the same range of capacities in the Westinghouse-Parsons machines. This may be understood after a consideration of the constructive features of the two patterns of turbines. In the Westinghouse-Parsons pattern, the

larger units are but magnified copies, if you please, of the smaller sizes, and thus the energy losses bear the same relation to the capacity in any sized unit. On the other hand, the smaller Curtis turbine units are constructively quite different from the larger machaines, and the ratio of energy losses to capacity is greater in the smaller sizes.

Figure 9, as mentioned above, presents the steam economy of Westinghouse-Parsons units of various rated capacities, under the actual operating conditions. It is significant that the curve of water rate of the 400 Kw. unit coincides with the curve of the 5500 Kw. machine up to their normal capacities. Both machines were operating under similar initial and final pressures, but the small unit was supplied with steam superheated 100°, whereas the initial steam for the large machine was saturated.

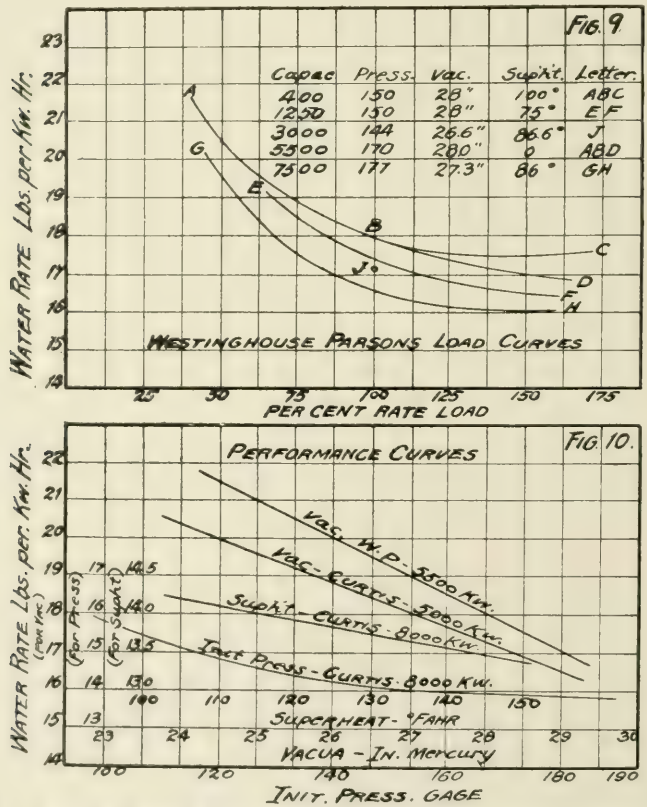


Fig. 9. Relative Steam Economy of Five Westinghouse-Parsons Units.
Fig. 10. "Performance Curves," Showing Relative Economy Under Different Conditions.

It is exceedingly important, as suggested above, that accurate means be secured for reducing the performance to a common basis for purposes of comparison, whether various types and sizes of units are involved, or the agreement of actual performance with guarantees in contracts is in question. For these purposes "performance curves" should always be determined which will present the variation in economy due to changing conditions of vacua, superheat, pressure, etc. Typical "Performance Curves" are shown in Figure 10. Most significant of these curves and most worthy of special mention is the Initial Pressure curve, which demonstrates the futility, from the standpoint of economy, of increasing the initial pressure much above 140 pounds gage. Up to this point the inclination of the curve is quite marked, and the advantage of increasing pressures as a means of reducing water rates very apparent. Beyond this point, the curve tends to become more nearly parallel to the pressure coordinate, indicating an advantage and that a somewhat questionable one, only in gaining capacity. This deduction is in accord with numerous investigations recently conducted, which have resulted in a diminishing of enthusiasm for high initial steam pressures. Some time ago, Professor W. F. M. Goss, Dean of the College of Engineering at the University of Illinois, at the time occupying a similar position at Purdue University, presented a paper, which has been widely distributed, based upon investigations of the influence of increasing boiler pressures upon the performance of steam locomotives. The results presented were in direct accord with the preceeding discussion. It will be of interest to mention that the government engineers in charge of the steaming tests have also advanced the proposition that lower steam pressures and high degrees of superheat will be found desirable and economical in the operation of steam prime movers. Curves of the same form as the one under discussion were secured in the Mechanical Engineering Laboratory at the University of Illinois from tests of a small turbine unit, of the velocity or impulse type.

For some reasons it would be desirable to present performance and load curves for many other turbines that are now playing an important part in the design and operation of power plants Numerous comparisons, however, have indicated that the curves here presented for the Curtis and Westinghouse-Parsons machines, representing, as they do, the two chief types of turbines, are characteristic both in form and in the absolute values given, of all steam turbines of their respective types.

Before passing from the consideration of steam economy, it will be well to consider examples of the numerous smaller machines that are attracting attention. Among the turbinees of this class that have appeared quite recently are the Kerr, the product of the Kerr Steam Turbine Company of Wellsville, New York; the Sturtevant,

recently perfected and now being vigorously supported by the B. F. Sturtevant Company, and the Terry, built by the Terry Steam Turbine Company of Hartford, Connecticut. These small machines are all of the multi-stage impulse type, the Kerr applying the principle of the Pelton wheel and all of the others mentioned being modifications of the Riedler-Stumpf patterns heretofore discussed.

These small machines are designed for relatively small capacities of from 15 to 200 brake horse power, and usually for some special application such as driving D.C. electric generators, blowers, centrifugal pumps, etc., or where close regulation is desirable at comparatively high speeds. In general, they are designed to operate non-condensing, with saturated steam, and under such conditions give practically the same steam economy as a well designed high

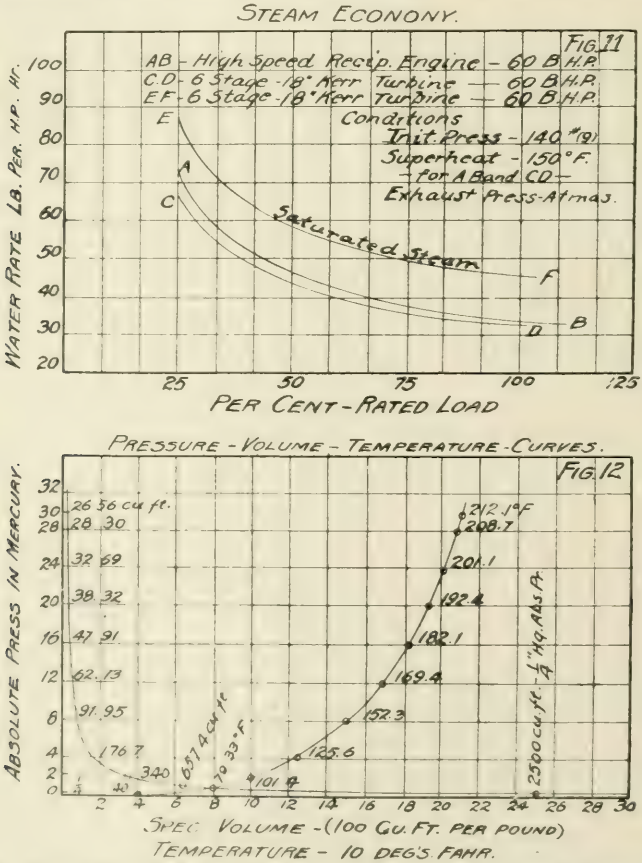


Fig. 11. Comparison of Steam Consumption of Turbine and Reciprocating Engine.

Fig. 12. Volume-Pressure and Temperature Curves.

speed reciprocating engine of similar capacity. The accompanying curves, Figure 11, show the close agreement of the steam economy of a high speed simple reciprocating engine, Curve AB, and a six stage Kerr Turbine, Curve CD, each rated at 60 brake horse power and operating with an initial steam pressure of 150 pounds gage, 150° Fahrenheit superheat, and exhausting to the atmosphere. Curve EF represents the steam economy of the same turbine, using saturated steam.

It will be observed that the superiority of the turbine is quite apparent at low loads, due, no doubt, to the reduction of the windage loss occasioned by the decrease in density of the steam at lower stage pressures, a fact that is characteristic of large as well as small units. In this connection it will be interesting to note the graphical representation in Figure 12, of the relation between Volume, Temperature and Pressures below atmosphere. The rapid increase in specific volume from 4 inches to ¼ inch mercury, absolute pressure, is closely related to the increase in turbine economy, noted in Figure 8.

LOW PRESSURE TURBINES.

A number of plants have been installed more or less recently that have employed low pressure turbines as prime movers, which are operating on the exhaust steam from reciprocating engines in the same station. By this means great economy is effected in the use of the steam, and a saving of practically 65% may be effected by the use of a high-vacua condensing equipment. Practically all of the builders of turbines of large capacity have developed low pressure turbines and these are playing a prominent part in the design of power plant extensions. Mr. Lionce Battu very ably discussed the principles involved, in his paper before this society in September, 1904. One of the prominent installations of low pressure turbines is in the power station of the Philadelphia Rapid Transit Company. This machine is an 800 Kw. Curtis turbine unit operating on the exhaust from Corliss engines and utilizing a vacuum of 28 inches. The guarantee provides that the steam consumption per kilowatt hour shall not exceed 36 pounds at full load, and 40 pounds at half load. Tests that have been made indicate a water rate well within the guarantee.[1] Tests made in the shops of the Westinghouse Company upon a 1250 Kw. low pressure unit have resulted in a water rate of 30 pounds per brake horse power hour, this being the equivalent of approximately 38 pounds per kilowatt hour.[2]

1—French's Steam Turbines.
2—J. R. Ribbins, Electric Journal.

HEAT EFFICIENCIES.

The Williams Robinson Company of England, the builders of a popular and efficient type of reciprocating engine, have been experimenting for some years upon improvements in the Parsons type of turbine. Results have been secured that are very satisfactory to the builders, and they are now doing a large turbine business. A contract recently entered into by this company for the construction and erection of a 3,000 Kw. unit contained a performance guarantee clause stipulating a water rate of 12.9 pounds per kilowatt hour. No data was presented with reference to the conditions of operation, but by reference to the curves of Figure 6, it will be seen that this is equal to the best performance of the 8,000 Kw. Curtis turbine.

Now, just what does it mean for a turbine to develop a kilowatt at the switchboard on a steam consumption of 12.9 pounds per hour? This is the equivalent of 9.54 pounds per E.H.P. or with a generator efficiency of 96% it is the equivalent of 9.17 pounds per brake horse power hour; further, assuming a mechanical efficiency of 94% for the prime mover, it is the equivalent of 8.62 pounds per indicated horse power hour, certainly a commendable performance. According to the British Standard as recommended in the report of the committee of the American Society of Mechanical Engineers on Standard Code for Steam Engine Tests, this performance gives a thermal efficiency of 21.4%, closely approaching the best performance of internal combustion engines. The "potential efficiency" of heat engines presents a much more satisfactory basis of comparison than "thermal efficiency" just discussed. This effieciency is defined as the ratio of the ideal to the actual heat change per unit of power. Assuming an absolute pressure of 190 pounds, 150° F. superheat and a vacuum referred to 30" barometer of 29", the above water rate is the equivalent of a potential efficiency of 67.7% based upon energy delivered to the switch board and 75% based upon indicated horse power deduced as explained above. In comparison it is interesting to note that the official trial of a 1000 I.H.P. double acting, twin compound Schmidt engine, operating on 155 pounds initial steam pressure, 25.4" vacuum and 330° F. superheat gave a potential efficiency of 83.3%. This represents the best modern practice.

Thus it will be seen that we are fast approaching the limit of economy in the prime mover itself, and future developments must be looked for in the steam generator. Greater economy must be secured in the performance of the boilers. It is significant that practically the same rated boiler capacity was installed for the first 5,000 Kw. Unit in the Fisk Street Station of the Commonwealth-Edison Company of Chicago, as seven years later, was installed to operate the 9,000 Kw. Units. This points to developments in boiler practice as well as to remarkable advances in the large turbo units.

BOILER ECONOMY.

In most plants, the steam driven auxiliaries do not furnish enough exhaust steam to heat the feed water above 120° Farhenheit. The possibility of increasing economy by using hot feed water has been taken advantage of in some cases by the installation of economizers, though their ultimate practicability still remains a much discussed question. Other engineers have taken steam from the second or third stage of the turbines to increase the feed temperature, and this without suffering a deleterious effect in economy.

In a recent article before the American Institute of Electrical Engineers, Mr. J. T. Findlay presented a very interesting discussion of experiments with double stoker boilers in the power plant of the Interboro Rapid Transit Company of New York City, made under the general supervision of Mr. H. G. Stott, superintendent of motive power of the Interborough Company. These boilers were 500 horse power units set with two Roney stokers, one as in the standard setting and the other at the rear at a somewhat lower level. The horizontal baffling was so arranged that the gases from both stokers intermixed and traversed the same passes over the heating surface. This increase in volume of gases, with the resultant higher velocity, effected an increase in capacity of 80 per cent with no appreciable difference in overall efficiency.

This suggests what is very much discussed, namely, the possibility of securing a greater amount of work from our boilers. It leads to the prediction that we are rapidly approaching the point when we will be able to rate water tube boilers on a basis of five square feet of heating surface instead of ten, as now used. Experiments such as are now being made, of which the one cited is a good example, foreshadow the design and operation of larger boiler units; the reconsideration of generally accepted theories regarding heat transmission through boiler heating surface, and the re-design of boiler settings that have been standard for years. There must be a constant striving for better evaporative performance; for a decrease in the radiation and unaccounted for losses in boiler practice if this factor in power plant development is to keep pace with the modern prime movers.

ARCHITECTURAL ACOUSTICS.

FLOYD R. WATSON, Ph. D.
Assistant Professor of Physics.

The faulty acoustics of many of our buildings is called to the attention of the public at frequent intervals either by an account in the papers of the poor acoustics of some new structure, or else by attendance in an auditorium where difficulty is experienced in hearing easily. The question usually asked concerning such a case is as follows: "Cannot architects construct buildings so as to avoid these difficulties?" The purpose of this article is to give an account of the work that has been done in attacking the problem.

The most decided advance in the subject has been made by Professor W. C. Sabine of Harvard University who pubilshed an account of his researches in the American Architect in 1900, and later a paper on the same subject in the Proceedings of the American Academy of Arts and Sciences in 1906. His work was on a practical basis from the start for the reason that he was called upon to propose a remedy for the acoustical difficulties presented in an auditorium just then completed at Harvard University.

In his analysis of the problem he states that three conditions are necessary for good hearing in any auditorium: the sound should be sufficiently loud; it should be free from resonance and interference, and spoken words should be clear and distinct.

These conditions are perhaps best understood by considering the case where a speaker addresses an audience. Sounds uttered by the speaker proceed in ever widening spheres until they strike the walls of the room and are reflected back and forth, a little energy being absorbed at each reflection, until they finally die out. When it is considered that sound travels about eleven hundred feet a second, it is seen that a lecture room of ordinary size is almost immediately filled with sound because of the many rapid reflections in all directions. The first condition of loudness is thus obtained. The walls and ceiling reflect to the audience the sounds that would be lost if the speaker were in the open air.

While the reflection of sound has the advantage of fulfilling the condition for loudness, it introduces at the same time certain disadvantages. Thus a reflected wave of sound in meeting an advancing wave may produce interference; that is, a reenforcement of the sound at some points and a comparative silence at others. It is a common experience in audience halls for an auditor to secure better hearing by moving his head to one side or the other; he

simply moves his ear from a position of reenforcement or silence to a position free from interference.

Another disadvantage introduced by the reflection of sound is the possibility that the words of the speaker may be made indistinct. If the auditor is near the speaker, the sound comes to him first directly, then by reflection an instant later. If a time interval of more than one-tenth of a second elapses between the direct and reflected sounds, he hears an echo, and consequently has trouble in following the words of the speaker.

The reflection of sound may also cause a reverberation. As a sound wave is reflected from wall to wall, a small amount of energy is lost at each reflection and the sound finally dies out. If the walls are good reflectors, the sound may persist several seconds. In the meantime, the speaker has uttered other sounds and these mix with the preceding ones thus causing a confusion that is called a reverberation.

The phenomena of resonance may be explained by considering first a mechanical example: a heavy iron ball suspended by a wire may be made to acquire a large swing by exerting a series of gentle pushes at the proper instants. So the sound waves, each one with small energy, act on a wall of the building at such intervals as to cause it to acquire considerable vibration and thus reenforce the sound. An oak door one and one-half inches thick was found by the author to vibrate preceptibly when acted upon by a suitable sound. In an auditorium this resonance is a defect if the sound is reenforced too much.

The conditions that fix the acoustics of a hall are thus set down. The next step in the solution of the problem is to consider the changes that are possible in a room that has bad acoustical properties. Professor Sabine assumed that only two variables exist in a room—shape including size, and materials including furnishings. As it is obviously impracticable to change the shape or size of a room without doing violence to the design of the architect, the only remaining means of cure is to change the materials or furnishings.

This latter change was the means used by Professor Sabine in perfecting a method of cure. In an interesting set of experiments lasting over a period of four years, he finally evolved a law expressed as follows:

$$t = 0.164\, V \div a,$$

where t is the time in seconds a sound will persist in a room after the source of sound is stopped, V is the volume of the room in in cubic meters, and a is the absorbing power of the room—the unit of absorbing power being taken as one square meter of open window space.

An inspection of the relation shows that for good acoustical conditions,—i. e., for a short time of duration of the sound, the volume of the room should be small and the absorbing power large.

This confirms experience when it is considered that good acoustics are found in a small room with plenty of rugs, cushions and other absorbing material. If the volume of an auditorium is large, the only cure lies in increasing the absorbing power.

Professor Sabine's method of taking measurements was to blow an organ pipe of five hundred twelve vibrations a second in a room and record by a chronograph the time of duration of the sound after the organ pipe stopped. The absorbing power of the room was then increased by bringing in more absorbing material and the time of duration again measured. The effect of different materials was tested in this way. An open window was considered to be a perfect absorber of sound because no sound that passes out ever comes back. The absorbing powers of different materials were determined in terms of open window space. Thus the absorbing powers of one square meter of wood sheathing and one square meter of open window space are as .061 to 1.000.

MATERIAL.	COEFFICIENT.
Wood sheathing, (hard pine)	0.061
Plaster on wood lath	.034
Plaster on wire lath	.033
Plaster on tile	.025
Glass	.027
Brick set in Portland cement	.025
Audience	.96
Oil paintings, (inclusive of frames)	.28
House plants, per cubic meter	.11
Carpet rugs	.20
Oriental rugs, extra heavy	.29
Cheese cloth	.019
Cretonne cloth	.15
Shelia curtains	.23
Hair felt, 2.5 cm. thick, 8 cm. from wall	.78
Cork 2.5 cm. thick loose on floor	.16
Linoleum, loose on floor	.12

MATERIAL.	ABSORBING POWER.
Audience, per person	0.44
Isolated man	.54
Isolated woman	.48
Plain ash settees, each	.039
Plain ash settees, per seat	.0077
Plain ash chairs, "bent wood"	.0082
Upholstered settees, hair and leather, each	1.10
Upholstered settees, per single seat	.28
Upholstered chairs, similar in style, each	.30
Hair cushions, per seat	.21
Elastic felt cushions, per seat	.20

With this table of absorbing powers at hand an architect can predict how long the sound will endure in a certain proposed building. It is only necessary to use the relation

$$t = 0.164\ V \div a,$$

and insert the value of the volume of the building for V and the sum of the absorbing powers of the walls, wood work, audience, etc., and the time of duration of the sound can be predicted before a brick of the building is laid.

It should be pointed out, however, that the method described in the preceding paragraph is true only for a sound whose pitch is five hundred twelve vibrations a second. It would not be exactly true for sounds of different pitch; the error, however, would not be of special importance as will be shown presently.

Professor Sabine, in a later investigation, showed that the duration of a sound depended on the pitch of a sound, and depended also on the amount of absorbing material present. As a concrete example, the high notes of a violin will be less reverberant with a full audience, than the lower notes of the bass viol, though they might have the same reverberation in the empty room. Again the voice of a man with notes of low pitch might give entirely satisfactory results in an auditorium, while the voice of a woman with higher pitched notes would be unsatisfactory.

These considerations show that no hard and fast conditions can be attained for any special auditorium. The audience may be large or small, and the speaker's voice high or low. The best soultion is a compromise where the average conditions are satisfied. Hence the solution as offered by Professor Sabine is an average solution, and will doubtless be satisfactory in any ordinary lecture hall.

The problem of architectural acoustics has been attacked by other workers than Professor Sabine. Professor G. W. Stewart[1] proposed a cure for the poor acoustical properties of Sibley Auditorium at Cornell University. His experiments confirmed the work of Sabine.

Marage[2], after investigating six halls in Paris, confirmed the method given by Sabine.

Exner[3] investigated the acoustical properties of an audience hall, and gave details, analagous to those already expressed in this paper, for the conditions for good acoustics.

Jacques[4] investigated the effects of air currents on acoustical properties of buildings. He states that acoustics were good when a gentle, steady current of air passed through the room, and adds

1 Sibley Journal of Engineering, May, 1903.
2 Compt. Rendus Vol. 142, page 878, 1906.
3 Zeitsch-des oesterreich Ingenieur und Architecten Verein, '05.
4 Phil. Mag. (5) Vol. 7, page 111, 1879.

that acoustics were unsatisfactory when the current was haphazard.

Jos. Henry[5] wrote an excellent article on "Acoustics Applied to Public Buildings"—his experiments and observations were made preparatory to designing an audience hall for the Smithonian Institution.

The author is also engaged on the problem by investigating the properties of the Auditorium at the University of Illinois, which offers an opportunity to investigate both echoes and reverberations. This investigation is not yet completed.

In conclusion it should be pointed out that the action of sound in a closed hall is dependent on many factors, and that the complete analysis of the problem has not yet been made. There remains to be investigated the influence of temperature, air currents, the form of the walls of a room, the material of the walls especially as regards porosity. The development of the subject is important not only because of the advance from the standpoint of pure science, but also from the practical side in suggesting proper materials and construction so as to avoid acoustical horrors as they exist at present.

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5 Smithsonian Report, 1856, page 221.

WHAT THE ELECTRICAL ENGINEER SHOULD LEARN IN COLLEGE.*

LOUIS A. FERGUSON.
Commonwealth Edison Company, Chicago.

Mr. Chairman and Gentlemen:

Professor Brooks has invited me to address you this afternoon and has asked me to give you my ideas of the training and qualities necessary to develop the successful electrical engineer. He has told me that I am not expected to make a formal address but rather to talk to you in a more conversational manner from the standpoint of one who was once, like yourselves, an engineering student and who has since graduation had some experience in the outside world into which you will soon enter.

The young man starting out in business mentally equipped as those should be who are graduated from the University of Illinois is at once at a distinct advantage over those less fortunate young men who have not had the benefit of such an education. I do not mean by this that the one who has tried to jam into his technical course the maximum amount of so-called knowledge consisting of the memorizing of data is necessarily better equipped to compete with his fellow men in after life. The mere memorizing of details and data is oftentimes accomplished at a sacrifice of a thorough understanding of fundamental principles, with the result that after the young man is out in business a short time he has forgotten much of the matter he is supposed to have acquired, and then roundly blames the teachers for forcing upon him—as he thinks—things which to him appear of no use to him in the world of practice.

The great value of an engineering education to a young man about to start in his life's work lies not so much in the actual amount of knowledge which he may bring with him, but in the training which he has received. The accumulation of a mass of data only to be soon forgotten because the opportunity for its use may not present itself, is not the important thing, but the reasoning power which comes from a thorough knowledge of fundamentals and underlying principles which he has acquired in his college work, if his instruction has been intelligently given and his studies properly guided, will serve him in good stead in after life and enable him to

*—An address delivered on the occasion of the visit of Mr. Ferguson, as President of the American Institute of Electrical Engineers, before a joint meeting of the Urbana section of the A. I. E. E. and the Electrical Engineering Society of the University.

grasp intelligently the matters daily before him and to cope successfully with the many varied problems which are presented to the engineer or business man for solution.

Technical training of this character, given in our engineering schools develops the analytical mind, increases the reasoning power, promotes accurate judgment and teaches the man to differentiate between right and wrong. The man so trained does not do things by rule of thumb; he decides because *he knows* and *acts* upon his own knowledge, and does not follow blindly the lead given by others who may perhaps be mistaken in their conclusions. A man so trained, if he should later occupy a position on the commercial or financial side of the business in which he is engaged, is not dependent on others in his negotiations with clever men of business; his training has taught him to think straight and quickly.

The very knowledge that he is perfectly able to discuss intelligently the problem at hand in all its phases will give him a distinct advantage over the untrained man and will inspire in himself confidence in his own undertaking and furnish the necessary courage to present his case with force and positiveness.

This courage shown by the trained man becomes persuasion, carrying with it conviction, and enables him to bring his work to a successful accomplishment.

Do not let me convey the impression gentlemen, however, that the young man fresh from a technical college knows it all and is vastly superior to his fellow man. This condition unfortunately prevails already to too great an extent among the young graduates, and I would shrink most decidedly from encouraging it even in the slightest degree as it is a feeling to be most heartily discouraged. Modesty is indeed a virtue in the college graduate, but diffidence if it exist must not be confused with modesty and must be conquered.

We have heard the argument advanced in isolated cases, and sometimes by men who have themselves been extremely successful in business of a more or less technical nature, that technical education is not a good thing for a man and does not produce the best results, that it is narrowing in its tendency and that technical men do not rise to the head of large institutions. These statements are not borne out by the facts. While the financial heads of the various industrial institutions may not be technically trained men in the ordinary acceptation of the term, yet the administrative and executive heads of the organization who are engaged in the daily management of the business and responsible for the economical manufacture and profitable sale of the products of our great industrial corporations are being drawn more and more from among the technically trained men. Those who argue against the technical man in business must remember that the great industrial development of this country has come within the last twenty-five years and that

in the early days of this development there were few technical men aside from civil engineers and architects.

Fifteen or twenty years ago the principal men on the selling side of industries even of a technical nature were those whose principal quailfication was in being a "good fellow," but those days have passed and it is now the man who has the goods and can demonstrate their value through his knowledge of the business that makes the sale. The purchaser is better fitted today than he was twenty years ago, has more general knowledge on all subjects of a technical character, even to having expert technical assistance at his call, and therefore I venture to say that the next twenty-five years will find the technically trained man the actual head of most industrial undertakings.

There is a tendency among some technically trained men, especially the younger set, who have been out of college but a short time and whose minds have not sufficiently matured through wide contact with the world, to feel that they should not devote any of their time and thought and energy to the commercial side of the business in which they are engaged as engineers; that it is unprofessional so to do and beneath their dignity. That this is a mistaken idea many of them realize in later years, when their success in life has not been as marked as some of their fellow men. They do not appreciate in time that all technically trained men cannot be great scientists and that there is a splendid field awaiting the use of their training if properly applied in the great market of commercial life.

This great United States of ours is not a country where caste prevails, where to be respected one must be either a soldier or a professional man. Ours is, at the present at least, essentially a commercial country and its prosperity and prestige will continue in the future to be developed and maintained by the commercial engineer working in the industrial field.

Why are the lawyers who have achieved marked success in their profession sometimes chosen to conduct the affairs of large undertakings? They are technical men. They are business engineers; they have been trained in the theory of what is right and wrong in business. Few lawyers of active temperaments would consider it beneath their dignity to give up a lucrative practice for the presidency of a large corporation or a great business. The same limitations that would apply to the engineer as to his capability for the conduct of a large business apply similarly to the lawyer. He must be broadly educated either originally in his college life or in after years by contact with men of broad ideas and experience.

There is probably no branch of engineering today in which the man requires so wide and varied a knowledge as in electrical engineering. The electrical engineer to be successful, as the world recognizes success, can not confine himself to the design of electrical

apparatus and the calculations of the sizes of conducting wires and other things purely electrical. He must have a broader knowledge of engineering and of affairs.

The graduate electrical engineer for some reason is considered by some employers to be devoid of ability to discuss anything but things electrical and his opinion on other matters is discounted and his advice ignored, oftentimes very unfairly to him. This is unfortunate and should be corrected as may be done if the man while a student as well as in after life realizes that a broad general education obtained not only from study but from observation as well is absolutely necessary to accomplish more than moderate success. The development of our industries is so rapid and so widening in its scope that subjects which were cast aside during his college years as not belonging to the profession of electrical engineering may be presented to the electrical engineer for solution, resulting in failure to him and necessitating his giving way to others more broadly trained and preventing his rising with the development of the industry.

The graduated student who intends to become an electrical engineer today should understand thoroughly the fundamental principles of mechanical engineering and civil engineering, chemistry and hydraulics, building construction and general business law as well as theoretical and applied electricity. A good knowledge of the modern languages such as French, German and Spanish is not only useful for the purposes of study but for actual service in the applications of electricity abroad. Every student should realize that such fundamental knowledge of the branches of engineering other than pure electrical as well as a broad general education is paramount to ultimate success in electrical engineering, and by that we mean assuming the responsibility of conducting large engineering undertakings or the management of large industrial operations.

The successful engineer like the successful man in any walk of life must have certain personal characteristics which may be natural to him or may be acquired. Personality counts for much in this world of ours. Not the superficial obtained by artificial outward appearance, but the real qualities which come from the higher cultivation of the mind, the strength of moral character and the healthy development of the body.

The power of observation is keenly developed in the successful man. He remembers what he sees and understands what he hears. Learning by observation is a perfectly natural quality. Little children learn to speak their native language and acquire their various mannerisms through observation of the adults with whom they are in daily contact.

Initiative is vital to success. The man who recognizes the car of opportunity as it approaches and boards it is the aggressive man who gets results. Without neglecting the duties of our own position

we should try to equip ourselves for that next higher in rank so as to be prepared to occupy it if the opportunity should be presented.

We sometimes hear engineers complain because their positions in the community are not recognized to the same extent as that of other men in other walks of life. The basic trouble is that some engineers devote all of their time to engineering and not to the other matters in which the community is interested and they are therefore counted men of narrow views. I would urge the engineer to devote a part of his time to public spirited work of a non-political nature. Engaging in such work will bring him in contact with the men of highest character in the community—usually with men who are in the habit of dealing with large affairs—and will develop him mentally, teach him to look at things from different points of view and have a decidedly broadening influence upon his character. Time and energy thus expended, while it may appear at the moment to be sacrificed, will ultimately make him more valuable to himself and to those by whom he is engaged.

One should be careful however in enlisting in such work that he does not drift into the class of destructionists whose efforts are expended against everything to which there may be attached any semblance of success. These men as a rule have nothing to lose and think to gain prominence by their attacks which bring them into the lime light, for which position they are constantly striving. Anyone may tear down but it takes brains and skill and energy to build up. Live in the atmosphere of optimism which is the harbinger of prosperity, and adopt a constructive policy in all your undertakings.

Be loyal and respectful to your superiors, fair and considerate to those under you. Do not be critical of your fellowman because he may appear to be less well informed on some subject than you are. Possibly he may be much better posted on other more important subjects than you are yourself.

Be tactful but never at a loss of sincerity.

When given a problem to solve or a matter to undertake do not come back to your employer and question him as to how to attack it; plan for yourself the means and methods of accomplishing the purpose; find the necessary information for yourself, for it is to be found somewhere. Your employer has not the time to arrange the details of your plan of procedure—he has assigned that to you, and what he expects from you is the result. Determine for yourself a fixed purpose in life and work steadily toward it in a straight line.

TEST OF A 3-KW. WESTINGHOUSE TYPE S TRANSFORMER.

ANTONIO GUELL, M. S., M. E.
HUBERT M. TURNER, E. E., '10.

Some time ago the Electrical Laboratory of the University of Illinois received a 3-kw. transformer sent for test by the Westinghouse Electrical and Mfg. Co., through Mr. W. R. Pinckard of Chicago. As this transformer represents the most modern practice of this company, being the result of exhaustive electrical research and careful mechanical design, it was with genuine interest and care that this test was conducted by the writers.

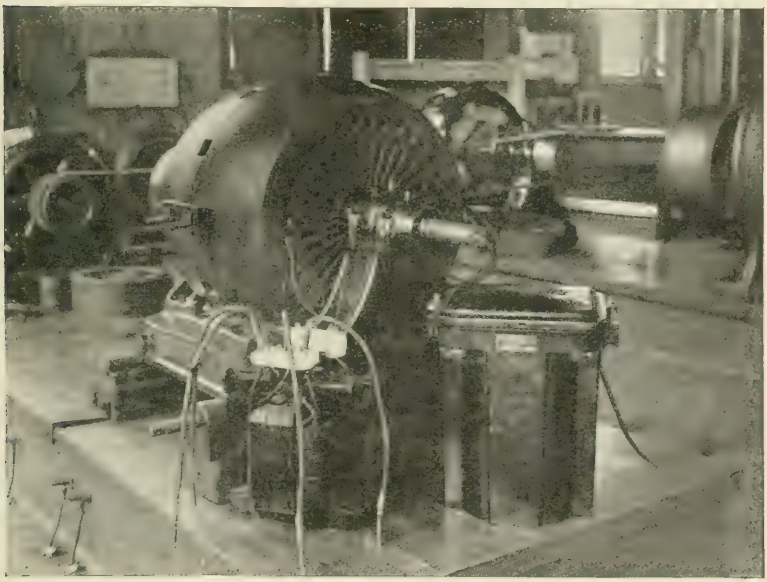
DESCRIPTION OF THE TRANSFORMER.—This transformer is mounted in a smooth, weather-proof cast iron case and gross weighs about 150 lbs., (or 50 lbs. per kw.). The core, which is of the shell type, is built up of laminated sheet steel punchings, and consists of four magnetic circuits encircling the winding and protecting it from mechanical injury. The high-tension winding is mounted concentrically between two low-tension coils. The core has the following dimensions: inside cross-sectional area, 7.55 square inches, containing 11.25 lbs. of iron (3.75 lbs. per kw.); outside dimension, 14.2 sq. in., containing 43.94 lbs. of iron (14.65 lbs. per kw.). The high-tension windings have 1480 turns (740 turns each coil) of 0.0403 in. round wire weighing 10.94 lbs., (3.65 lbs. per kw.). The low-tension windings have 148 turns (74 turns each coil) of 0.064 by 0.005 in. double (two wires in multiple), and weigh 10.19 lbs. (3.4 lbs. per kw.). The windings completely fill the openings which are 2 3-16 by 5 3-16 in.

An examination of the interior of this transformer revealed the fact that the "much-abused" tape is noticeable by its absence. Between the high- and low-tension coils are layers of paper and mica, and the whole winding is insulated from the core by means of strips of press-board 3-16 in. thick. The insulating compound with which the core and coils are impregnated (by the vacuum process) not only improves the insulation but also makes the winding oil- and moisture-proof. On the other hand, the presence of this insulating compound makes repairs more difficult.

The normal frequency of this transformer is 60 cycles, but its design permits of its being used on circuits of any frequency from 50 to 140 cycles. The lower curves in Fig. 10 and 11 prove this conclusively. The voltages of the secondary and primary windings are 110-220 and 1100-2200, respectively.

SOURCE OF POWER.—A 10-pole 7.5 kw. inductor alternator built by students of the University of Illinois, driven by a 15-h. p., 220-volt Westinghouse direct current motor. Although the shape of the wave of this inductor alternator differs from the standard sine wave, this machine was selected because its e.m.f. and frequency could be varied widely.

INSTRUMENTS.—The instruments used were always calibrated after the particular test had been completed. Both a speed counter and a tachometer were used for determining the speed of the alternator.



Alternator and Transformer upon Which the Test was Conducted.

CORE LOSS.—The hysteresis loss and the eddy current loss were determined for the following conditions:

(1) Variable pressure and constant magnetization.
(2) Variable pressure and constant frequency.
(3) Variable frequency and constant pressure.

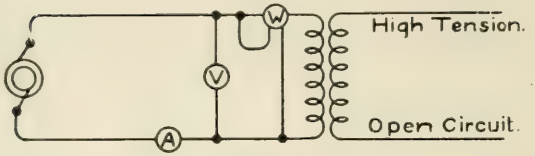


Fig. 1.

Fig. 1 shows the connections for determining the core loss for conditions (1), (2), and (3). V is a voltmeter, W a wattmeter, and A an ammeter.

(1) *Variable Pressure and Constant Magnetization.*

(a) 60-CYCLE, 110-VOLT ADJUSTMENT.—The inductor alternator was run at 720 r.p.m. (60 cycles) and the field current was adjusted to obtain 110 volts, normal pressure. With the field current constant, the speed was changed from 473 r.p.m. (39 cycles) to 1442 r.p.m. (120 cycles) while the pressure was varied from 72.3 to 221 volts. Columns 1, 3, 5, and 7. Table I, give the readings obtained. Column 4 shows plainly that during the test the magnetization remained fairly constant. The two secondary coils were in parallel.

TABLE I.

SEPARATION OF CORE LOSS (COLD). 60-CYCLE, 110-VOLT ADJUSTMENT. CONSTANT B.

(1) Volts	(2) (1)/(3) =Z	(3) Amp.	(4) (2)/(9) =L	(5) Watts	(6) (5)/(8) =W/f	(7) Speed R.P.M	(8) f	(9) $2\pi f = \omega$
72.3	113.3	0.638	0.457	18.4	0.467	473	39.4	248
83.6	131.5	0.636	0.458	21.9	0.481	546	45.6	287
91.2	143.0	0.638	0.457	23.7	0.477	595	49.7	313
102.7	160.3	0.640	0.457	27.6	0.493	670	55.9	352
110.3	172.0	0.640	0.454	30.1	0.502	720	60.0	377
124.5	194.0	0.641	0.454	34.6	0.510	813	67.8	427
123.6	193.0	0.641	0.454	34.4	0.512	807	67.3	424
134.4	208.0	0.645	0.452	37.9	0.518	878	73.2	461
144.4	223.0	0.647	0.451	41.7	0.528	943	78.7	495
154.4	238.0	0.650	0.450	45.0	0.534	1008	84.1	529
164.2	252.0	0.650	0.448	48.6	0.543	1073	89.4	562
175.0	268.0	0.654	0.447	52.8	0.554	1143	95.3	600
184.4	282.0	0.654	0.447	56.3	0.561	1204	100.4	632
198.2	302.0	0.656	0.445	62.2	0.577	1293	107.8	678
219.0	330.0	0.663	0.440	67.2	0.564	1430	119.2	750
221.0	332.0	0.665	0.440	71.7	0.597	1442	120.1	755

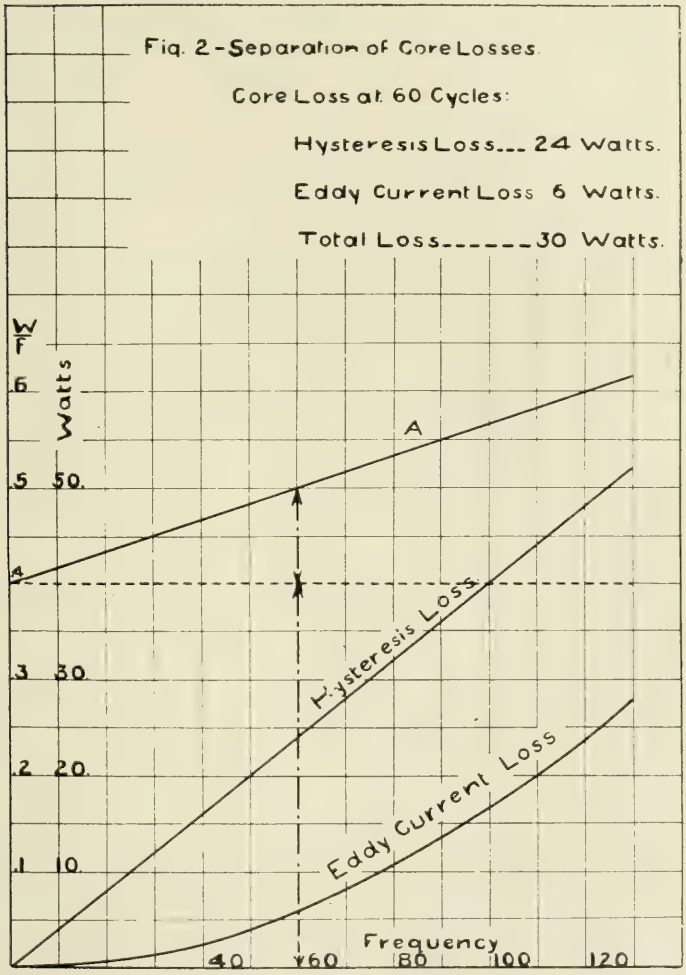
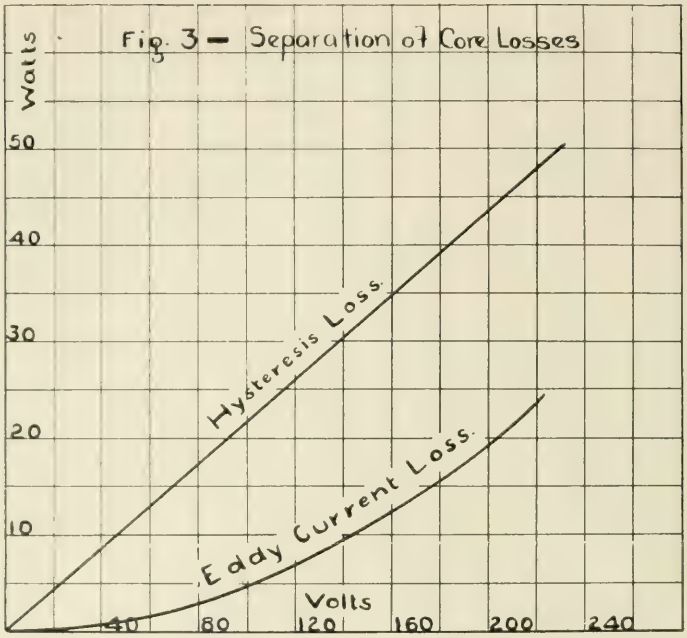


Fig. 2 shows the graphical separation of the core losses at 60 cycles. Using the values given in Table 1, a curve was plotted with watts divided by frequency as ordinates, and frequency as abscissas. The curve (a straight line if the readings are correct) was produced until it cut the Y-axis. A horizontal line was drawn through the point of intersection dividing each ordinate into two parts; the upper and lower part multiplied by the corresponding frequency gave the hysteresis loss and the eddy current loss respectively, as shown in



Figs. 2 and 3. This graphical separation is based on the fact that with magnetization constant the hysteresis loss varies as the frequency f, while the eddy current loss varies as the square of the frequency. This may be represented by the formula

$$W = k_h f + k_e f^2 \qquad (1)$$

where W = core loss, watts,
k_h = hysteresis constant,
f = frequency, cycles per second,
$k_h f$ = hysteresis loss, watts,
k_e = eddy current constant,
$k_e f^2$ = eddy current loss, watts.

Dividing (1) by f, we get,

$$W \div f = k_h + k_e f$$

which is the equation of a straight line. (See Fig. 2).

(b) 120-CYCLE, 110-VOLT ADJUSTMENT.—The inductor alternator was run at 1440 r.p.m. (120 cycles) and the current in the field was adjusted to obtain 110 volts, normal pressure. With the

TABLE II.

SEPARATION OF CORE LOSS (COLD). 60-CYCLE, 110-VOLT ADJUSTMENT. CONSTANT B.

(1) Volts	(2) (1)/(3) =Z	(3) Amp.	(4) (2)/(9) =L	(5) Watts	(6) (5)/(8) =W f	(7) Speed R.P.M	(8) f	(9) $2\pi f = \omega$
57.6	174	0.331	0.442	10.1	0.161	752	62.7	394
70.2	209	0.336	0.436	12.2	0.160	917	76.3	480
82.4	243	0.339	0.431	15.0	0.167	1078	89.7	564
95.8	277	0.346	0.422	18.1	0.173	1253	104.5	657
101.7	289	0.351	0.414	19.5	0.176	1326	110.7	697
110.3	311	0.354	0.412	21.5	0.179	1440	120.0	755
115.7	323	0.358	0.408	23.0	0.183	1510	125.7	791
122.5	339	0.361	0.404	24.5	0.184	1600	133.3	838
134.4	368	0.365	0.401	27.6	0.189	1755	146.2	919

field current constant, the speed was changed from 752 r.p.m. (63 cycles) to 1755 r.p.m. (146 cycles) while the pressure was varied from 57.6 to 134.4 volts. Table 2 and Figs. 4 and 5, for this adjustment, were obtained following the method used for the 60-cycle, 110-volt adjustment.

From Fig. 2 the total core loss at 60 cycles (e.m.f. constant at 110 volts) is 30 watts, 24 watts (or 80%) corresponding to the hysteresis loss, and 6 watts (20%) to the eddy current loss. From Fig. 4 the total core loss at 120 cycles (e.m.f. at 110 volts) is 21.6 watts, of which 15.6 watts (or 72%) is the hysteresis loss and 6 watts (or 28%) the eddy current loss. Therefore, the total loss at 60 cycles is 39% higher than at 120 cycles, the hysteresis loss is 54% higher, and the eddy current loss has the same value for both frequencies.

With constant e.m.f., the eddy current loss at 60 and 120 cycles may be obtained with the aid of the formulas,

$$W_e = k\, f^2\, B^2 \qquad \text{(for 60 cycles)}$$

and

$$W_e = k\, (2f)^2\, (B \div 2)^2 \qquad \text{(for 120 cycles)}$$

where k is a constant and B is the maximum flux density for the 60-cycle, 110-volt adjustment. These two formulas clearly show why the foucault current loss should be the same for these two adjustments. The general formula for the effective e.m.f. (see Double Voltage Test) may be written

$$E = k\, f\, B$$

where k is a constant. Therefore, if B is divided by 2, f must be multiplied by 2 in order to keep E constant, which is the case under consideration.

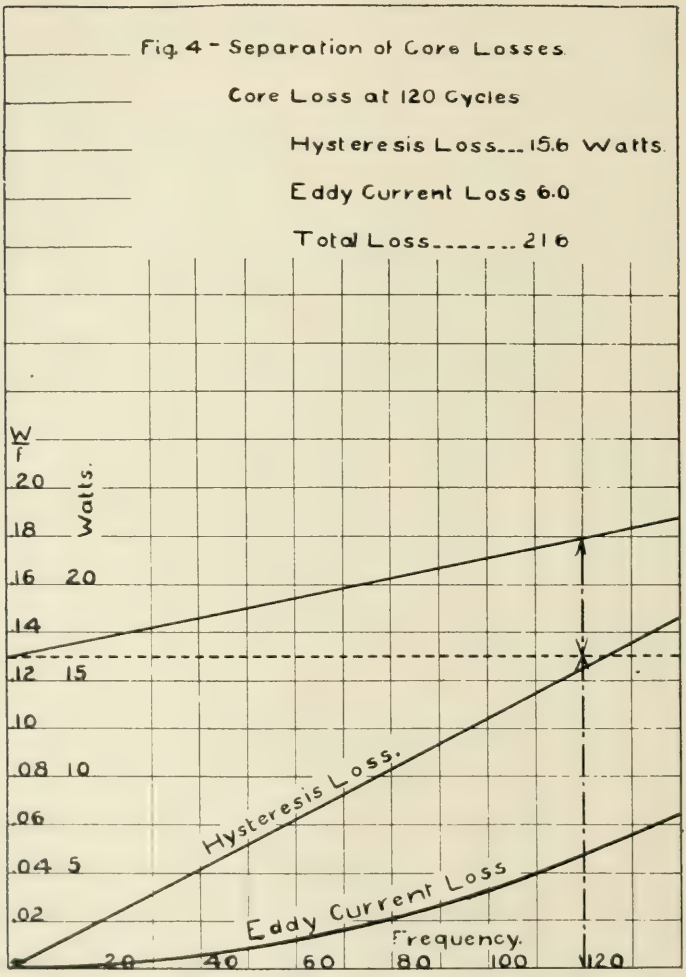
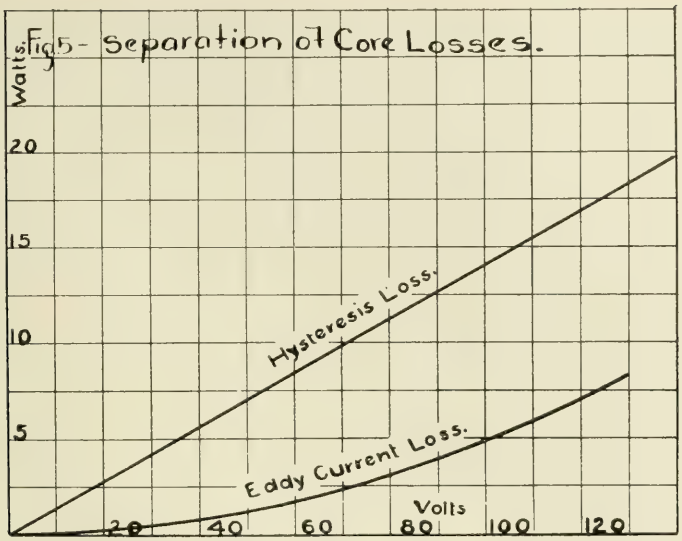


Fig. 4 - Separation of Core Losses.
Core Loss at 120 Cycles
Hysteresis Loss.... 15.6 Watts.
Eddy Current Loss 6.0
Total Loss..... 21.6
W/f
Watts.
20
18
16
14
12
10
08
06
04
02
20
15
10
5
Hysteresis Loss.
Eddy Current Loss
Frequency.
20
40
60
80
100
120



(2) *Variable Pressure and Constant Frequency.*

(a) CONSTANT FREQUENCY = 60 CYCLES.—Table 3 gives readings of volts, amperes and watts obtained with frequency constant at 60 cycles. The hysteresis loss and eddy current loss were

TABLE III.

CONSTANT FREQUENCY, 60-CYCLES. VARIABLE E. M. F.

(1) Volts E_1	(2) Amp	(3) Watts W_1	(4) $E_2 f_1 / f_2 = E_1$	(5) Watts Interpolation W_2	(6) Hysteresis Loss	(7) Eddy Loss	(8) Log W_h	(9) Log E_1
35.1	0.258	3.6	70.2	9.6	2.40	1.20	0.380	1.545
54.7	0.317	8.8	109.4	21.1	7.05	1.75	0.848	1.738
67.9	0.364	12.8	135.8	31.0	10.10	2.70	1.004	1.832
80.1	0.417	16.9	160.2	41.6	13.00	3.90	1.114	1.904
91.9	0.485	21.8	183.8	53.9	16.65	5.15	1.221	1.963
97.2	0.515	23.8	194.4	60.2	17.50	6.30	1.233	1.988
105.7	0.587	27.8	211.4	71.0	20.10	7.70	1.303	2.024
114.3	0.688	32.1	228.6	83.8	22.30	9.80	1.348	2.058
119.6	0.765	34.7	239.2					
127.7	0.968	39.0	255.4					
136.4	1.530	45.5	272.8					
143.4	2.440	52.3	286.8					
147.4	3.250	57.2	294.8					

separated (see Fig. 5) by means of a simple and accurate method given by Prof. H. S. Carhart in the Electrical World, vol. 31, p. 306. This method is based on the measurement of these combined losses at two frequencies. A series of measurements is made at at each frequency for a number of different voltages. From these two series we may obtain several pairs of equations connecting together the hysteresis and eddy current losses, each pair being taken for the same value of the maximum instantaneous induction B of the magnetic wave at the two frequencies. The general formula for the effective e.m.f.,

$$E = \sqrt{2}\,\pi\, f\, n\, A\, B \times 10^{-8} \text{ volts},$$

where f is the frequency,
n, the number of turns of wire,
A, the cross section of the iron,
B, the maximum induction,

shows plainly that if B is kept constant E varies as f. Therefore, if B is kept constant, then,

$$E_1 \times \frac{f_2}{f_1} = E_2$$

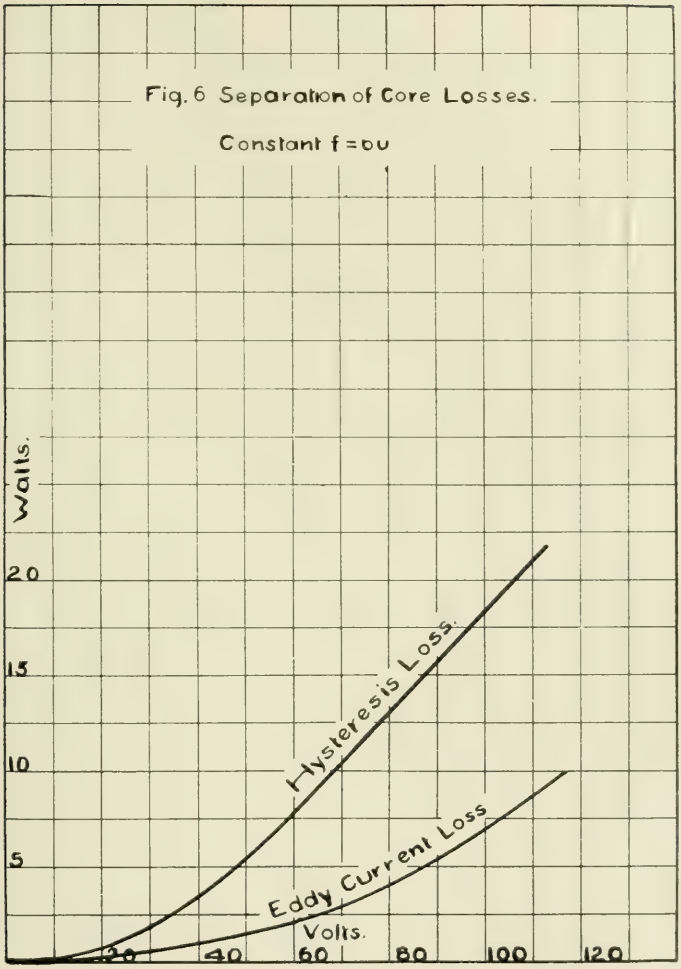
where E_2 is the corresponding voltage at frequency f_2. Now, by means of a curve expressing the relation between volts and total iron loss for the second frequency, we may easily find the total loss corresponding to voltage E_2.

If W_1 and W_2 are the total losses for the two frequencies f_1 and f_2, both with the same value of B, and k_h and k_e are constants, then

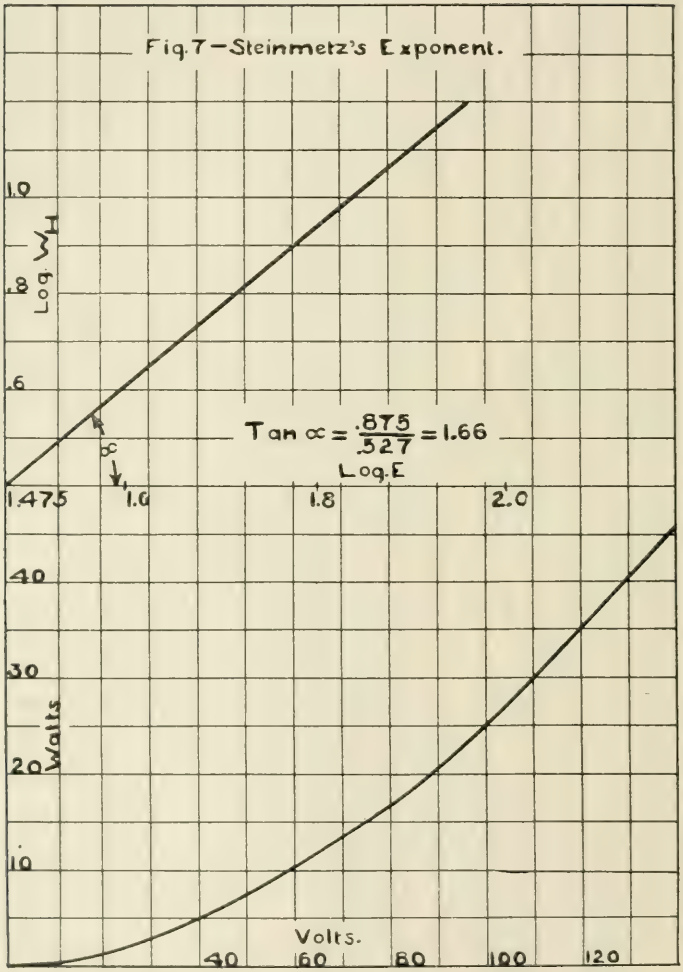
$$W_1 = k_h f_1 + k_e f_1^2 \qquad (1)$$

$$W_2 = k_h f_2 + k_e f_2^2 \qquad (2)$$

where $k_h f_1$ is the hysteresis loss and $k_e f_1^2$ is the eddy current loss for the first frequency. With the help of formulas (1) and (2) and the lower curve in Fig 9 the losses were separated as shown in columns 6 and 7 of Table 3, and by the curves in Fig. 6.



The exponent of B in Steinmetz's formula for the hysteretic loss, was determined using the value of W_h (hysteretic loss, watts) and of E (volts) given in columns 6 and 1 of Table 3. E was used instead of B because, f being a constant, the voltage is proportional to the magnetic induction. Therefore, the formula $W_h = c\ B^x$ where c is a constant and x the Steinmetz's exponent, may be written $W_h = k\ E^x$, where k is a new constant. Hence; $log\ W_h = x\ log\ E + constant$. The relation between the logarithms of W_h and E (columns 8 and 9, Table 3) is the equation of a straight line, and the desired exponent x is the tangent of the angle which this line makes with the axis of *log* E (see Fig. 7).



(b) CONSTANT FREQUENCY = 120 CYCLES.—By means of the curve in Fig. 7 and the values given in Table 4, the hysteresis and

TABLE IV.

CONSTANT FREQUENCY, 120-CYCLE. VARIABLE E.M.F.

(1) Volts E_1	(2) Amp.	(3) Watts W_1	(4) $E_1 f_2/f_1 = E_2$	(5) Watts Inter-polation W_2	(6) Hyster-esis Loss	(7) Eddy Loss	(8) Log W_h	(9) Log E_1
55.6	0.243	6.0	27.80	2.5	4.0	2.0	0.602	1.745
71.8	0.279	10.4	35.90	4.0	5 6	4.8	0.748	1.856
80.1	0.298	12.4	40.10	4.8	6.8	5.6	0.833	1.904
89.6	0.315	14.8	44.80	6.0	9.2	5.6	0.964	1.952
100.8	0.329	18.4	50.40	7.7	12.4	6.0	1.093	2.003
111.8	0.354	22.0	55.90	9.2	14.8	7.2	1.170	2.048
123.6	0.380	26.2	61.80	11.0	17.8	8.4	1.251	2.092
123.4	0.381	26.3	61.70	11.0	17.7	8.6	1.248	2.091
141.8	0.423	33.8	70.90	14.0	22.2	11.6	1.346	2.152
155.3	0.459	39.2	77.65	16.4	26.4	12.8	1.422	2.191
164.1	0.486	43.6	82.05	18.0	28.4	15.2	1.453	2.215
183.5	0.561	53.9	91.75	21.8	33.3	20.6	1.522	2.264
204.1	0.684	67.3	102.04	26.3	37.9	29.4	1.579	2.310

eddy current losses were separated from the total iron loss in a manner similar to that already explained when the frequency was kept constant at 60 cycles and the e.m.f. was varied. (See Fig. 8). The Steinmetz's exponent for a frequency of 120 cycles per second was found to be 1.73, as shown in Fig. 9.

(3) VARIABLE FREQUENCY AND CONSTANT PRESSURE.—Table 5 gives readings taken for the separation of the core losses when

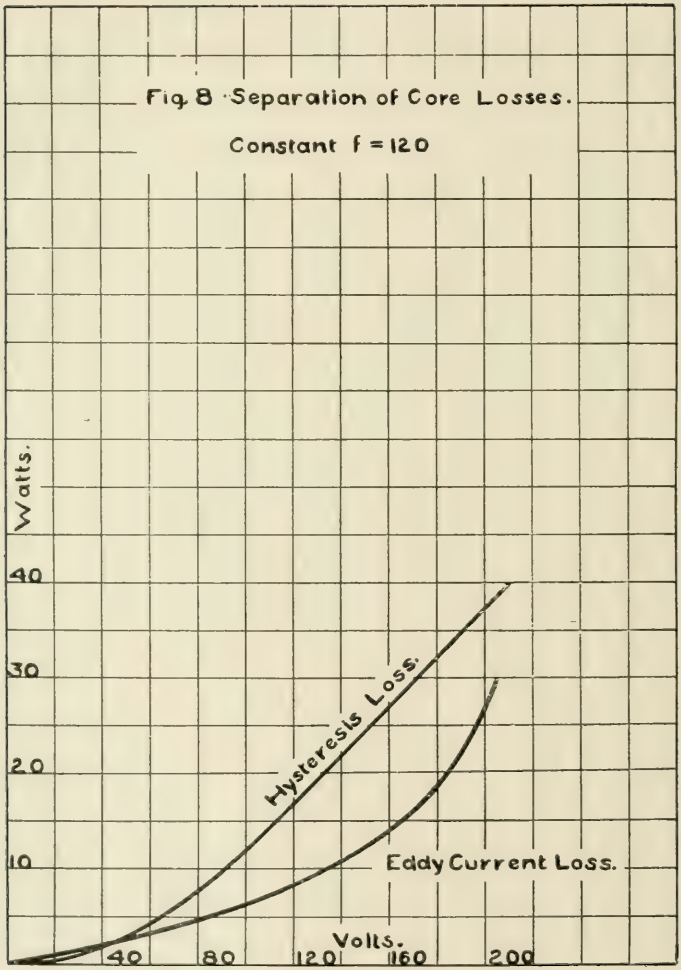


Fig. 8 Separation of Core Losses.
Constant f = 120
Watts.
40
30
20
10
Hysteresis Loss.
Eddy Current Loss.
Volts.
40
80
120
160
200

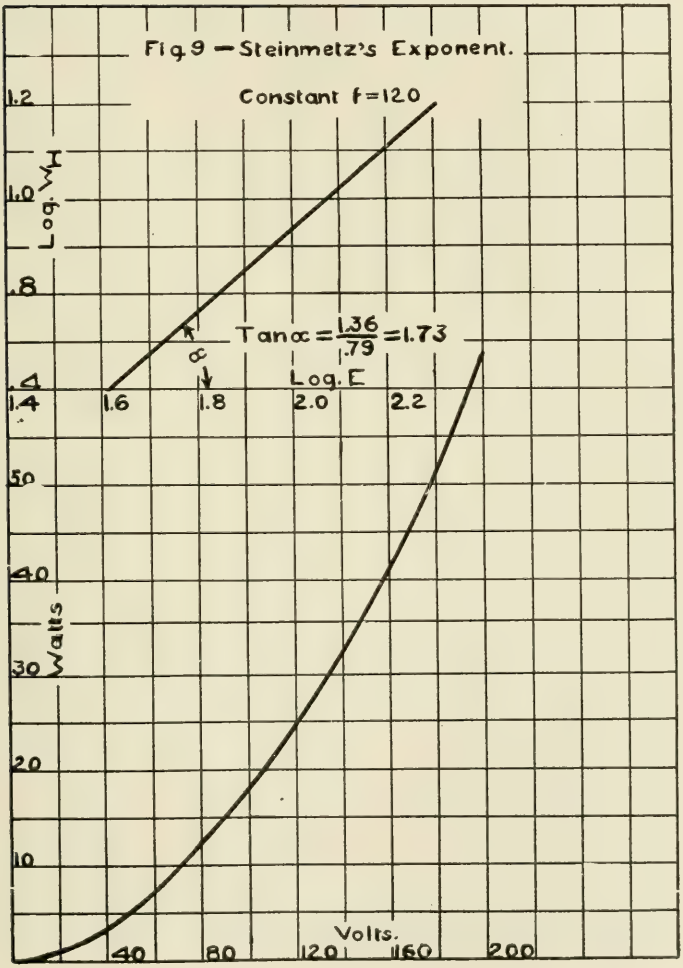


Fig. 9 — Steinmetz's Exponent.
Constant f=120
Log. WH
1.2
1.0
.8
.4
Tan α = 1.36/.79 = 1.73
α
Log. E
1.4
1.6
1.8
2.0
2.2
50
40
Watts
30
20
10
Volts.
40
80
120
160
200

TABLE V.

CONSTANT E. M. F. VARIABLE FREQUENCY.

Volts	Amp.	Total Loss Watts	Speed R. P. M.	Frequency	Hysteresis Loss Watts	Eddy Loss Watts	Per cent. Exciting Current
109.8	3.300	40.8	527	43.8	33.3	7.5	12.1
110.3	1.740	36.3	568	47.3	28.8	7.5	6.4
"	1.080	33.4	617	51.4	25.9	7.5	4.0
"	0.635	30.8	724	60.3	23.3	7.5	2.3
"	0.543	28.2	795	66.2	20.8	7.4	2.0
"	0.649	26.3	918	76.5	18.9	7.4	1.7
"	0.412	24.5	1074	89.6	17.6	7.9	1.5
"	0.379	23.0	1230	102.4	16.1	7.9	1.4
"	0.353	21.7	1428	119.2	14.5	7.2	1.3
"	0.330	20.2	1680	140.0	13.0	7.2	1.2

the e.m.f. remained constant and the frequency varied from 40 to 140 cycles. For this special case the following formulas were used:

$$W_1 = k_h f_1^{-0.66} + W_e \qquad (1)$$

$$W_2 = k_h f_2^{-0.66} + W_e \qquad (2)$$

$$k_h = \frac{(W_1 - W_2) f_1^{0.66} f_2^{0.66}}{f_2^{0.66} - f_1^{0.66}} \qquad (3)$$

where W_1 = total iron loss at frequency f_1, $k_h f_1^{-0.66}$ = hysteresis loss, and W_e = eddy current loss. This last loss, as seen from equations (1) and (2), remains constant at all frequencies when the e.m.f. is kept constant. Column 8, Table 5, gives exciting cur-

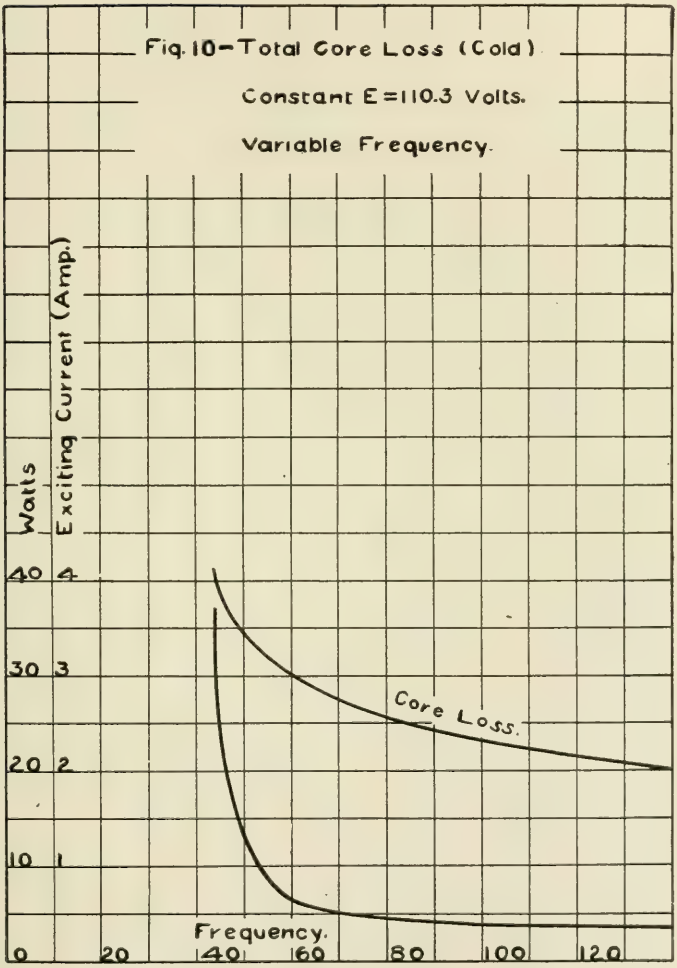


Fig. 10—Total Core Loss (Cold)
Constant E=110.3 Volts.
Variable Frequency.
Watts
Exciting Current (Amp.)
40
4
30
3
20
2
10
1
0
20
40
60
80
100
120
Frequency.
Core Loss.

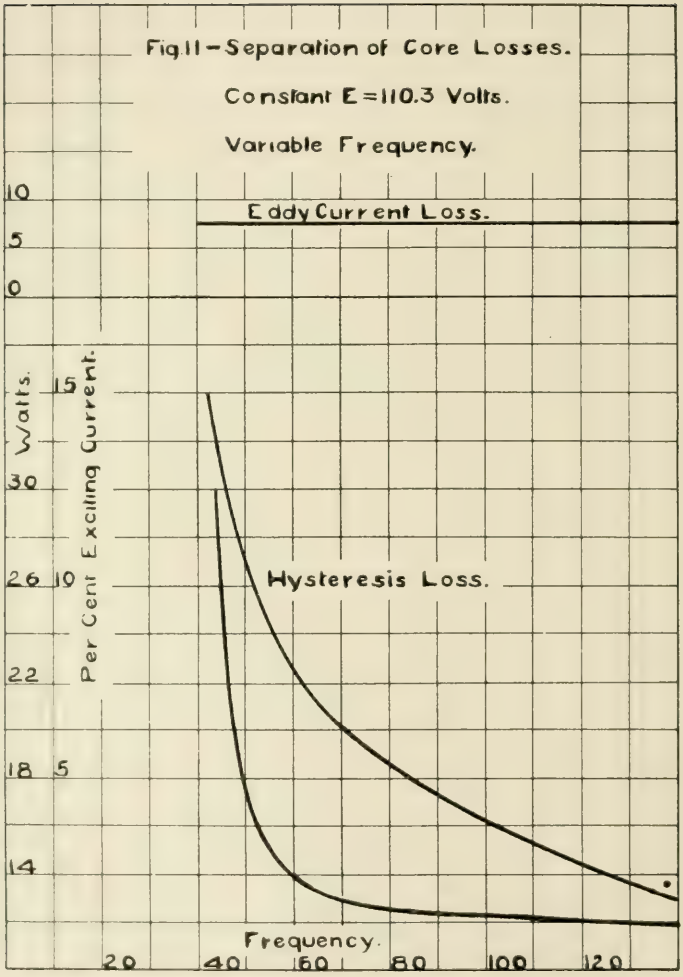


Fig. 11 – Separation of Core Losses.
Constant E = 110.3 Volts.
Variable Frequency.
Eddy Current Loss.
Hysteresis Loss.
Watts.
Per Cent Exciting Current.
Frequency.
10
5
0
15
30
26
10
22
18
5
14
20
40
60
80
100
120

rent in per cent of full-load current. Fig. 10 shows two curves, one drawn with total loss in watts as ordinates and frequency as abscissas, the other with exciting current in amperes as ordinates and frequency as abscissas. Fig. 11 shows the separation of the hysteresis and eddy current loss. The lower curve in Fig. 11 gives exciting current at different frequencies in per cent of full-load current.

Measurement of Resistance.

The resistance of the transformer windings, which must be known in order to determine the efficiency and regulation, was measured by the fall-of-potential method. Table 6 gives observed values

TABLE VI.

MEASUREMENT OF RESISTANCE.

Secondary			Primary		
Ampers	Volts	Ohms	Ampers	Volts	Ohms
8.6	0.378	0.0439	0.775	2.57	3.310
14.75	0.650	0.0441	0.950	3.13	3.294
18.25	0.808	0.0442	1.080	3.58	3.310
22.90	0.960	0.0418	1.250	4.15	3.310
27.10	1.125	0.0414	1.380	4.58	3.310
31.20	1.310	0.0419			
35.20	1.480	0.0421			
12.20	0.520	0.0426			

of current and voltage for both the high-and low-tension windings. The resistance was calculated from Ohm's law, $R = \frac{E}{I}$. At a temperature of 25.5° C. the resistance of the low-tension windings was found to be 0.043 ohm, and that of the high-tension coils, 3.32 ohms.

Double Voltage Test.

With connections as shown in Fig. 1 (omitting the wattmeter) and with frequency constant at 60 cycles, the pressure was increased

TABLE VII.
DOUBLE VOLTAGE TEST.

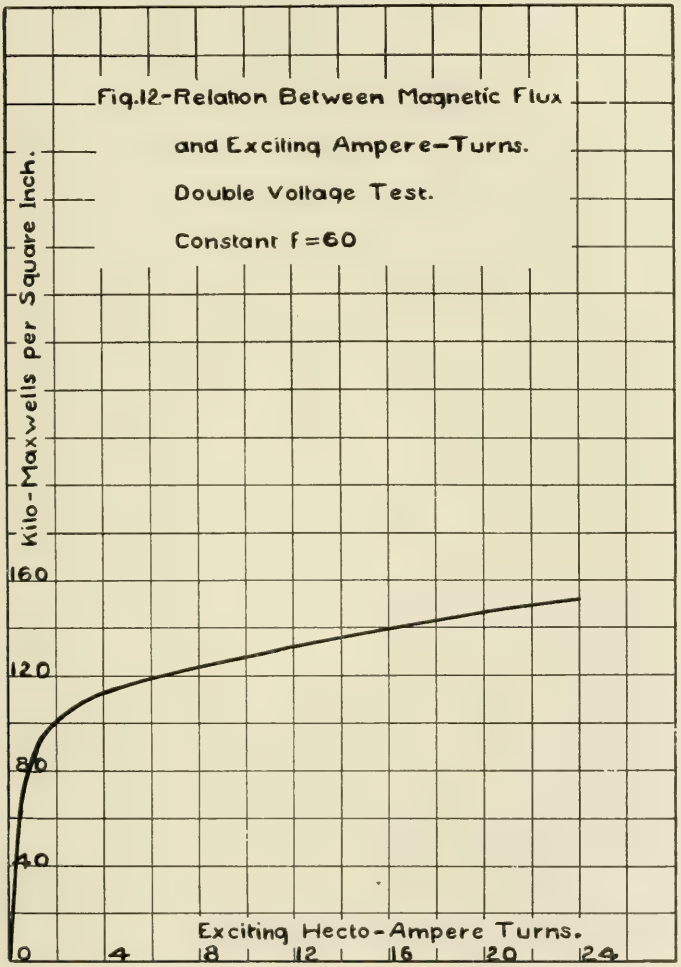
Volts	Amperes	B Lines per sq. in.	Exciting Ampereturns
35.1	0.258	23,580	19
54.7	0.317	36,750	23
67.9	0.364	45,620	27
80.1	0.417	53,820	31
91.9	0.485	61,750	36
97.2	0.515	65,310	38
105.7	0.587	71,020	43
114.3	0.688	76,800	51
119.6	0.765	80,360	57
127.7	0.968	85,800	72
131.2	1.140	88,150	84
145.4	2.110	97,690	156
153.4	3.060	103,070	227
158.2	3.860	106,290	286
161.2	4.540	108,310	336
167.1	5.460	112,270	404
173.0	7.340	116,240	544
181.9	9.980	122,220	738
188.9	12.900	126,920	955
196.2	15.520	131,830	1150
202.0	18.240	135,720	1350
206.5	20.840	138,750	1540
212.0	23.730	142,440	1760
220.0	27.590	147,820	2040
224.0	30.180	150,500	2240

by steps from 35 to 224 volts (about twice the normal voltage). Table 7 gives the data obtained. Column 3 was calculated with the aid of the general formula

$$B = \frac{E \times 10^8}{\sqrt{2}\,\pi f n l} = \frac{E \times 10^8}{4.44 \times 60 \times \frac{148}{2} \times 7.55} = 671.9\ E$$

(lines per sq. in.)

where B is the maximum induction, E the effective e.m.f., f the frequency, n the number of turns (secondaries in multiple), and A the cross-section of the iron. Column 4 gives the exciting current multiplied by 74 (turns).



The curve in Fig. 12 shows the relation between magnetic flux and exciting-ampere-turns. It is to be noticed that the knee of the curve is reached at a pressure of 130 volts.

Short Circuit Test.

Table 8 gives readings obtained with connections as shown in Fig. 13. Both the impedance drop and the combined $I^2 R$ loss were de-

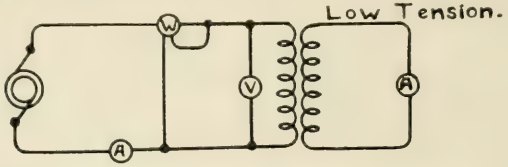
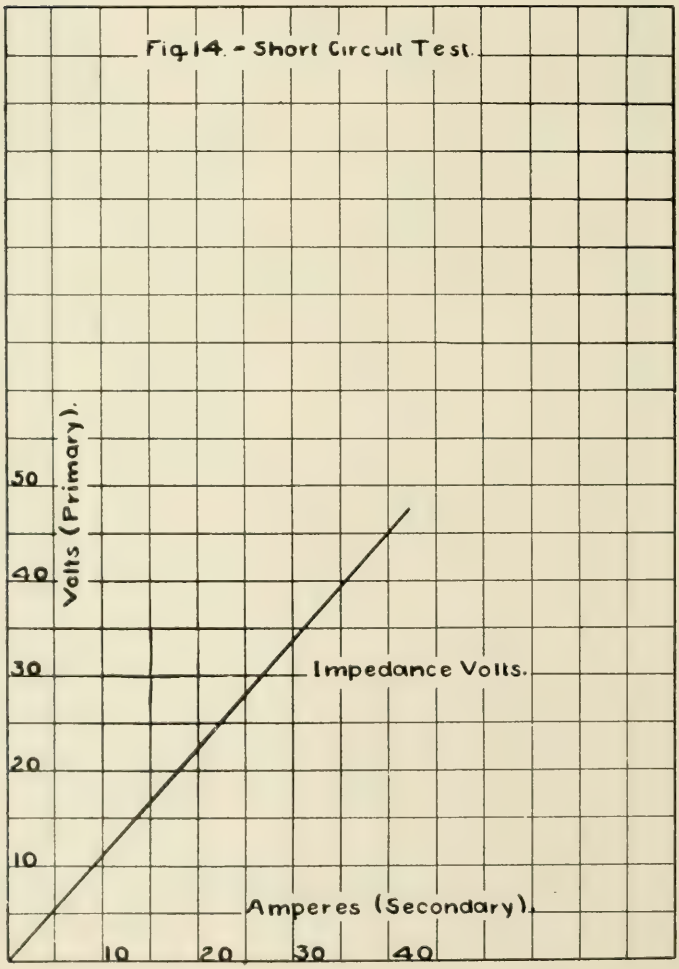


Fig.13-Connections for Measuring Impedance.



termined for a frequency of 60 cycles, the primaries and secondaries being in multiple. Fig. 14 gives a curve drawn with impedance volts (primary) as ordinates and secondary amperes as abscissas.

TABLE VIII.

SHORT-CIRCUIT TEST.

Amperes Secondary	Amperes Primary	Volts Primary	Watts Primary
5.37	0.63	6.03	2.5
6.16	0.71	7.09	3.2
8.20	0.88	9.06	6.0
9.48	1.01	10.43	7.7
14.00	1.55	14.39	17.8
15.60	1.70	17.20	21.4
17.10	1.86	18.70	26.3
19.30	2.08	21.70	34.3
21.30	2.26	23.20	42.1
25.40	2.75	28.70	61.1
28.30	3.07	32.70	76.2
29.90	3.23	33.60	85.1
32.00	3.41	36.40	97.5
34.10	3.56	38.80	110.3
36.10	3.81	40.80	126.6
38.60	4.08	43.90	145.0

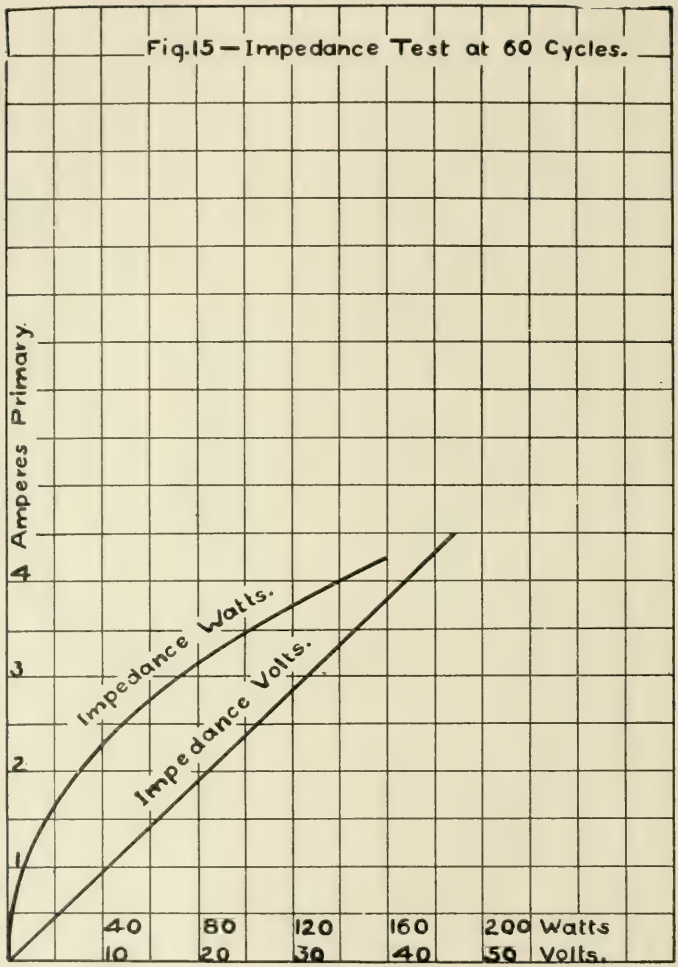


Fig. 15 gives the usual curves of impedance volts and impedance watts, with primary amperes as ordinates. Fig. 17 shows a curve drawn with copper loss as ordinates, and secondary amperes and load in per cent as abscissas. From Fig. 15, the impedance drop at full load, with normal voltage and frequency at 60 cycles, is

$$\frac{30}{1100} = 2.7\ \%$$

Load Test.

The Westinghouse transformer was loaded by means of a lamp bank on the secondaries of two other transformers. Fig. 16 shows the connections used for this test. The low-tension coils, as well as the high-tension windings, were connected up in multiple. With pressure and frequency constant (110.3 volts and 60 cycles, respec-

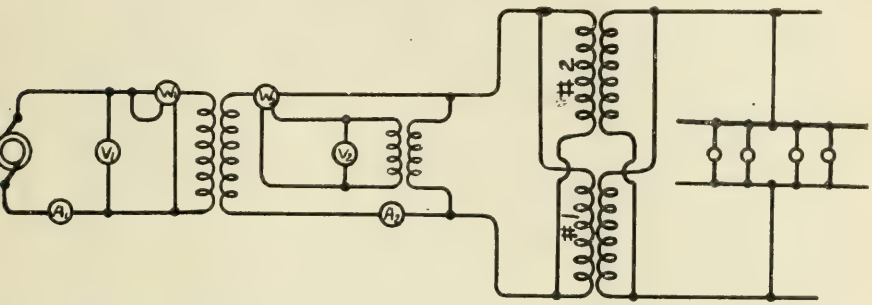


Fig.16 - Connection for Load Test.

TABLE IX.

LOAD TEST. PRIMARIES AND SECONDARIES IN MULTIPLE.

Low Tension			High Tension		
Volts	Amperes	Watts	Volts	Amperes	Watts
110.3	32.07	3475	1092	3.23	3235
"	28.78	3175	1092	2.86	2870
"	27.49	3025	1096	2.74	2770
"	24.02	2650	1099	2.40	2380
"	19.90	2176	1104	1.96	1945
"	14.51	1616	1110	1.43	1531
"	10.49	1176	1114	1.15	1095
"	4.83	510	1109	0.42	469
"	1.83	80	1124	0.10	50
"	0.00	0	1128	0.00	0

tively), the lamp load was decreased from 17% overload to zero load. Table 9 gives readings of volts, amperes, and watts taken for both the low- and high-tension sides of the transformer. At the end

of this test, which lasted about an hour, the resistance of the low- and high-tension windings was found to be 0.0465 and 3.57 ohms, respectively, at a temperature of 40.9° C. From Table 9, the regulation drop is

$$\frac{1128 - 1096}{1096} = \frac{32}{1096}, \text{ or } 2.9\%.$$

The regulation drop as obtained from the load test cannot be relied upon on account of the small difference between the full-load and no-load values, and the liability to error in measuring either of them. The calculated regulation drop (the more accurate method) will be given further on.

Efficiency.

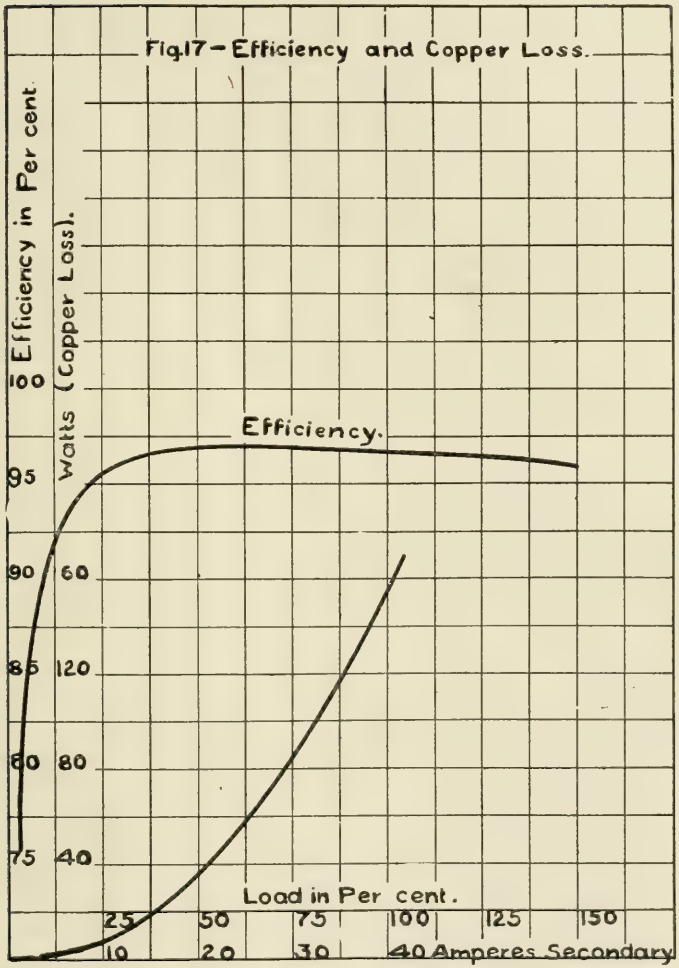
The efficiency of a transformer may be represented by the formula $\frac{W}{W + W_h - W_e + W_c}$, where W is the output (non-inductive load), W_h the hysteresis loss, W_e the eddy current loss, and W_c the copper loss. Of course these losses should be determined at the rated frequency and voltage. Column 7 of Table 10, calculated with the aid of the above formula, gives efficiencies for several

TABLE X.

EFFICIENCY FROM LOSSES.

Load in %	Load Watts	Copper Loss Watts	Hysteresis Loss Watts	Eddy Current Loss	Input Watts	Efficiency in %
25	750	4	24	6	784	95.7
50	1500	16	24	6	1546	97.0
75	2250	39	24	6	2319	97.0
100	3000	72	24	6	3102	96.7
125	3750	111	24	6	3891	96.4
150	4500	163	24	6	4693	95.9

loads. (See Fig. 17). Column 3 gives the copper loss (see Fig. 17), and columns 4 and 5 were obtained from the curves in Fig. 3.



The all-day efficiency of a transformer is the ratio of the *out put* to the *in put* during 24 hours. As the usual conditions of practice will be met if the calculation is based on 3 hours at full load and 21 hours at no load, using Table 10 we find the all-day efficiency of the Westinghouse transformer to be

$$\frac{3000 \times 3}{3000 \times 3 + 30 \times 24 + 72 \times 3} = 90.6\ \%$$

Regulation.

The regulation of a transformer is the ratio of the rise of secondary voltage, from full load to no load, to the secondary voltage (the primary pressure remaining constant), this ratio being expressed in per cent. It has been mentioned before that this method of determining regulation is by no means reliable owing to the small difference between full-load and no-load values of the secondary voltage. The more reliable method is to calculate the regulation drop from the separate measurements of resistance, reactive drop and magnetizing current. The following simple and accurate formula, developed in the Engineering Department of the General Electric Co., (see circular No. 8317), was made use of in determining the regulation for non-inductive load:

$$E = \sqrt{(100 + PIR + WIX)^2 + (IX)^2} \qquad (a)$$

where E is the no load voltage expressed in per cent of the full load voltage, P is the power factor of the load, IR is the total resistance drop expressed in per cent of rated voltage, IX the reactive drop similarly expressed, and W the wattless factor of the primary current. The following data, obtained from the different tests, are necesary for the solution of (a):

Primary resistance, R' equals 3.57 ohms at 40.9° C.,

Primary $I'\,R' = 2.75 \times 3.57 = 9.82$ volts, or $\frac{9.82}{1100} = 0.88\%$,

Secondary resistance, $R'' = 0.0465$ ohms at 40.9° C.,

Secondary $I''\,R'' = 27.5 \times 0.0465 = 1.28$ volts, or $\frac{1.28}{110} = 1.16\%$,

Total $I\,R = 0.88 + 1.16 = 2.04\%$,

Impedance drop (Fig. 14) $= 30.7$ volts, or $\frac{30.7}{1100} = 2.8\%$,

Ohmic drop, $I\,R = \frac{Watts}{I'} = \frac{69}{2.92} = 23.6$, or $\frac{23.6}{1100} = 2.14\%$.

(See Fig. 15)

Reactive drop $IX = \sqrt{(IZ)^2 - (IR)^2} = \sqrt{(2.8)^2 - ((2.14)^2} = 1.81\%$

Magnetizing currents $= \sqrt{(\text{Exciting Current})^2 - (\frac{\text{Core Loss}}{\text{Voltage}})^2}$

$$= \sqrt{(0.64)^2 - (\frac{30}{110})^2} = 0.578 \text{ or } \frac{0.578}{27.5} = 0.021 \text{ (See Table 1)}$$

For non-inductive load, W = magnetizing current expressed as a decimal fraction of full load current = 0.021, and $P = 1$. Substituting in formula (a),

$$E = \sqrt{(100 + 2.04 + 0.021 \times 1.81)^2 + (1.81)^2} = 102.10$$

Therefore, the regulation drop for non-inductive load is 2.10% of secondary full-load voltage.

For inductive load:

$$E = \sqrt{(100 + PIR + WIX)^2 + (PIX - WIR)^2} \qquad \text{(b)}$$

where $P = cos\ \Phi$, as before, and $W = sin\ \Phi$ = *magnetizing current.* (See Table 11).

Conclusions.

An inspection of the foregoing results will clearly show that this 3-kw. Westinghouse Type S transformer possesses some remarkable features which up to the present time have been absent in the smaller transformers.

The first row in Table 11 gives the manufacturer's guarantee

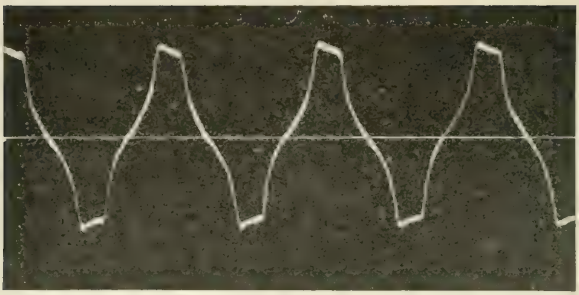
TABLE XI.

PERFORMANCE OF 3-KW. TYPE S TRANSFORMER.

Watts Loss		Per cent. Efficiency				Per cent. Regulation				(*)
Core	Copper	Full Load	3/4L.	1/2L.	1/4L.	100% P. F.	90%	80%	60%	Per cent. Exciting Current
34	64	96.8	97.0	96.8	95.2	2.16	2.79	2.91	2.88	3.00
30	72	96.7	97.0	97.0	95.7	2.10	2.67	2.75	2.70	2.34

(*) In per cent. of full load current.

(see Descriptive Leaflet No. 2227, Jan., 1909), and the second the results obtained by the writers, which, as seen, are better than the manufacturer's guarantee. The discrepancy between these two results can be ascribed to two causes: (1) that the guarantee applies rigidly to the average transformer; (2) that the inductor alternator used by the writers does not give the standard sine wave. Fig. 18 shows an oscillogram of the e.m.f. wave of this alternator. It was taken at no load, 60 cycles, 110 volts.



Oscillogram of E. M. F. Wave from Inductor Alternator.

An inspection of the lower curve in Fig. 11 shows that 50 cycles is the lowest frequency at which the transformer should be operated, because at lower frequencies the exciting current increases too rapidly. In fact, the best range is 60 to 140 cycles per second.

It is a well-known fact that a transformer with the least total loss at full load although having the greatest maximum efficiency may not have the greatest all-day efficiency. This shows that sometimes it may be of advantage to put many turns of wire in the coils of a transformer, thus increasing the copper loss, and decreasing the iron loss by making the core smaller.

It has been proved experimentally that those transformers in which the iron loss is small have a higher range of frequency, which, of course, makes unnecessary the purchase of a special and more expensive type for the lower frequencies. The transformer under consideration has a small core loss and a high copper loss.

Table 11 shows that the core loss is unusually small, and this, of course, will make the all-day efficiency high (see "Efficiency" for proof).

The point of maximum efficiency, clearly shown in Fig. 17, lies between ½ load and ¾ load. This is a most desirable feature, its desirability being apparent when we consider that in the majority of cases, especially in residence lighting, the average load on a transformer is not over one-half of its capacity.

The shell type of transformer protects the winding from mechanical injury but makes repairs more difficult. In this type the iron is cooler than the rest of the transformer; in the core type it is hotter. As the "aging" of the iron, or the increase of the hysteresis coefficient with time, is believed to be aggravated by heat, this is claimed as a point of superiority of the shell type. On the other hand, the core type has the advantage that the coils run cooler because of their being more thoroughly surround with oil than those of the shell type.

In conclusion, it may not be amiss to state that the writers have endeavored to be absolutely impartial, and that every precaution was taken to provide against inaccuracy.

SMOKE AND THE PUBLIC HEALTH.*

Dr. W. A. Evans
Commissioner of Health, Chicago.

In 1907 Chicago had 32 000 deaths. Of these 9000 were due to what we term bad air diseases,—consumption, pneumonia, bronchitis and influenza. In 1908 there were 30 000 deaths and 8000 deaths from this group of disease. In order that you may understand the importance of these figures, compare the 4900 deaths from pneumonia with the 376 from typhoid; the 3700 from tuberculosis with the 500 from diphtheria. Splitting the decennial period 1898-07 in two and comparing the last half with the first, and speaking in terms of deaths per 100 000 living, we find that deaths from all causes improved 26.2. A part of this was due to the following items: Improvement in acute contagious diseases, 13.2; impure water diseases 11.7; impure food diseases, 10.8. But in the impure air diseases there is a loss of 21.7. All of the effort had been exerted on contagious diseases, impure water and impure food. The related groups improved. The pollution of the air goes unchecked. The deaths resulting increase.

In 1908 war was waged on the impure air diseases. Comparing 1908 with the whole of the 10-year period just cited, and still speaking in deaths per 100 000 living, we find an improvement in the general death rate of 46, an improvement in the bad air disease of 46. Most of that was in pneumonia. The consumption improvement was slight. But the people who died of consumption in 1908 got it, in the main, in 1907 and 1906. The consumption death rate of 1909 will be a better index of etiologic conditions in 1908 than was the consumption death rate of 1908.

As you see, a little effort is doing a lot of good. Some of this effort is being put forth by the Smoke Commission, some by the Health Department, some by the manufacturers, some by the doctors, but, most of it is the effort of the people themselves.

You will note that I am talking about air pollution and bad air diseases and not specifically about smoke. Now, what are the air factors in these bad air diseases?

As I treat the subject from the disease standpoint, I must maintain my perspective, though I realize that you who work in fuel stand closer to smoke and therefore with you it looms larger than

*Delivered as an address before the Illinois Fuel Conference at The University of Illinois, March 12, 1909.

I indicate. The most important item of air pollution is the bacterial flora thereof; the tubercle bacilli pneumococci, diphtheria, scarlet fever and measles germs, pink eye, influenza and other bacteria of occasional interest.

I wish to make qualifying statements:

FIRST:—Pathogenesis does not persist more than a few minutes when the germs are brought in contact with sunlight and a good grade of air. Therefore not all of the germs or bacteria which get into the air are capable of spreading disease. Much of the dust is quite harmless. I rode with the First Cavalry from Chicago to Fox Lake and back last July. My usual station was at the rear of the column. There were 600 men and more horses; at times the dust made it impossible to see objects 40 feet away. There were no colds. The same exposure to the infected dust of Chicago streets would have caused colds and pink eye to be nearly universal.

SECOND:—Carriers are not of the consequence sometimes thought. The entirely well man whose mouth harbors pneumococci or diphtheria bacilli is usually doing no harm. In the process of habituation the host changes the bacillus about as much as the bacillus changes the host. The spreader is the convalescent and the man actively sick.

The second factor is trade dust. This dust is composed of fractured particles with sharp edges. The workman usually works just before a dust making machine or tool, therefore he is the point of maximum concentration. The dust of the more dangerous trades has no sulphurous acid to stifle and no odors to offend, therefore it is tolerated. For all of these reasons trade dust ranks second to bacterial flora.

In the whole population, bad air diseases cause 30 per cent of the total deaths. In metal polishers and stone cutters actively working, they cause 90 per cent of the total mortality.

THIRD:—The third factor is excretory air. It has been difficult to decide just what is the harmful factor in expired air. No specific poison has been demonstrated. No extraction has been accepted. CO_2 is held to be of minor consequence. Pflugge's opinion that is due to temperature acting on the peripheral nerve endings of the body is the most popular view at the present time. No one had been able to demonstrate just the poisonous agent in the other excreta. This is true of the urine and the faeces. With excretory air, urine and faeces the position is the same. The product is poisonous—efforts at further analysis have been fruitless. The opinions other than Pflugge's are moderately harmful. Pflugge's is positively harmful in that it leads entirely away from the one known fact—that the product is poisonous. It has one element of truth—cold air environment is beneficent, warm air environment is harmful. The reason is that waste air expired into an environment of cold air, being hot, will at once rise out of the breathing zone and

thereby becomes harmless. Unless engineers calling themselves ventilating experts put outlets at the floor and inlets at the ceiling. Whenever the laws of men run counter to the laws of God man suffers.

FOURTH:—I mention odors out of order to get the subject out of the way—odors serving as warnings have helped health rather than hindered it. The little health harm which they do—causing nausea, worry and hysteria in those who get excited about them—is offset by their efficacy in keeping people away from bad places.

FIFTH:—Smoke. How does smoke do harm? It fills the air with carbon particles, with CO_2, CO, SO_2 and with volatile oils. Most smoke ordinances are based on the density of smoke. I have been greatly interested in the London effort to rid their laws of the dense smoke provisions. This discussion is to be found in the Journal of the Royal Sanitary Institute for 1907. It is beginning to appear with us. For example: A few weeks ago I was visited by the agent of one skyscraper complaining of a neighboring building. Brother Bird had forced a proper fire box into the building complained of. There was no smoke. But there was a colorless gas which stifled those into whose office windows it blew.

Smoke carbon is probably as little harmful as any solid which can be taken into the human body. It is quite inert chemically. Physically it irritates but little. The harm that it does is that it transports bacteria and secures entrance for them where alone they would be repulsed. In bacteriology we have an illustration of this principle in tetanus, which affects much more uniformly in mixtures than it does alone. In physics we have the sludge filtration methods of water purification.

Sulphur compounds are very objectionable and probably more harmful. Probably before long our dense smoke ordinances will be changed so as to add to the carbon control other provisions which will control sulphur compounds. Possibly, also combustion experiments will likewise be directed more to the solution of the sulphur problem.

Markel suggests that sulphur has something like a ferment action in the air in that it tends to be automatically renewable. He says sulphurous acid falls on iron and is at once oxidized into sulphuric acid. It corrodes the iron and makes ferrous sulphate. This picks up oxygen from the air and makes basic ferric sulphate. This picks up iron and makes ferrous sulphate and iron oxide. The rust drops off, and a new sulphur cycle is started. Rideal found that white-washed walls were of great service where gas was burned as the lime took up the sulphur from the air. Amounts of sulphur found in the air at different analyses are: London (Rideal) .015 to 0.77 grams per 100 cu. ft. The same at Manchester. At Kew an analysis of dust from an exposed surface showed 2 per cent sulphur. Other figures for sulphur are: Cohen and Heffort say that

for 100 lbs. of sulphur in coal 71.78 lbs. will go off as sulphur gases; 14.51 lbs. will be absorbed by the soot and escape with it and 13.71 lbs. will remain in the ash. In London each day 981 792 lbs. of sulphur is poured into the air from coal consumption; from gas 893 lbs., from mineral oils 743 lbs.

In Glasgow and Manchester 20 tons of sulphur escape daily in the smoke.

Fats and oils are of increasing importance from the standpoint of air pollution. In this the automobile is a bad offender. Indirectly the oiling of the streets which has come about through the influence of the automobile has added to the proportion of oils and fats in the air. Cohen says that in Leeds 15 per cent of the soot is mineral oil. This is less than the Chicago figures. Fats and oils probably harm health in the same indirect way as does carbon but in a lesser measure. This may not be true of gasoline and the products of incomplete gasoline combustion.

CO_2 and CO: The present tendency is to believe that we can stand much higher percentages of CO_2 than are ever found in the outside air. That the devastating waves that follow volcanic eruptions are due to CO, to sulphur gases, and to other gases and not to CO_2. CO is directly toxic. CO_2 is depressent and remotely toxic and therefore for both of these reasons it is harmful. It does not kill in one whiff in any concentration. Neither does a child get a complete education in five minutes in a grammar school. Some figures are—Schafer says that London pours 1000 000 tons of CO_2 into the air each day as smoke. Every ton of completely consumed coal pours about three tons of CO_2 and CO into the air.

The volume of dirt which will deposit from the air ranges from 1 to 6 tons per acre per year, according to the location with regard to smoke and dust producers. It ranges broadly in quality. Near a boulevard it is rich in oils; near a brick kiln or a factory or locomotive yards it is rich in sulphur and in carbon monoxide. Near an elevated road it is rich in iron.

How else does it do harm?

1st. It kills vegetation. Rough equilibrium between animal and vegetable life is required to maintain atmospheric chemical equilibrium. Our 2¼ million people huddled on a few square miles —at places living 300 to the acre—need trees and grass. Our soil is sandy and poor; it is drained dry. It is covered by roofs and paving. Vegetation at best has a hard time. Smoke stops up its pores with carbon and with oil. The oil picks up other dirt. The SO_2 poisons when it exceeds one part in one million. Many kinds of vegetation will not live at all times without washing, and grooming trees is expensive.

2nd. It decreases sunlight. Sunlight is needed to kill bacteria and to purify the air. It adds to the cost of lighting. The St. James Gazette says that smoke costs London $73,000 a day for ex-

tra lighting bills. Such figures are little better than guesses. Aside from the money, these extra lights add to the harm of smoke to health.

3rd. It assists the formation of fogs. The air heavy with suspended solids becomes surcharged with moisture and this is fog. Fogs are disease breeders.

4th. There are wastes aside from direct health matters which are of consequences.

(a) The loss of fuel values; the large economics of this you are engaged in working out.

(b) The laundry cost of smoke is enormous.

(c) The loss to non-washing clothes, in stores and out, is very great.

(d) The increased painting and whitewashing expense is very great; paint is made dingy and is renewed, whitewash becomes gysum and no longer looks white. In coal districts it is cheaper to let the weather destroy the wood than to try to protect it with paint or whitewash.

(e) Metal structures are corroded by the sulphur gases and other gases with free bonds.

(f) Wooden work is less durable as well as less sightly.

(g) Property values of adjacent properties are lowered oftentimes to a non-productive basis.

(h) It serves to lower the general tone of a community.

A spotless town is more apt to be moral than a dirty town. It is useless to try to get a spotless town and leave the smoke. If the air is dirty it is very hard to get the streets, the yards, the clothes, the people clean.

THE COOPERATION OF PRACTICAL AND SCIENTIFIC MEN.*

G. W. TRAER.
Representing the Illinois Coal Operators.

It is a sincere pleasure to me to acknowledge, on behalf of the mine owners of Illinois, the obligations of humanity to the men whose efforts have made it possible that this great, civilized, Christian, work shall be carried on here, and whose time and thoughts are being given to it.

Illinois is to be congratulated upon the proprietorship of a University so situated that it is chosen by the federal government to participate in a work of this kind, and with a University organization qualified and eager to do so in the interest of humanity.

Special danger of injury and death never can be entirely eliminated from coal mining and many other industrial occupations. But such danger is multiplied by ignorance, indifference and lack of foresight; or it may be vastly lessened by research and application and unreserved cooperation on the part of those whose duty it is to think and apply, with those who think and experiment. Our modern civilization is equally distinguished by a wholesome regard for lives and happiness of all human beings and by its profound scientific achievements directed towards the same end.

We are here today to witness the dedication of a work of scientific research to that end. And although we may well realize how much remains to be done, we are justified in a feeling of confidence when we reflect upon the achievements of science in the past. Seventy-two years ago Macaulay wrote his great essay on Lord Bacon, who was the prophet and the apostle of the practical sciences, as we now know them. Bacon had been dead more than two hundred years when Macaulay wrote this brilliant eulogy on the practical results of what had once been called the new thought, and which, in advance of actual achievement, many people had considered to be merely theoretical, just as many people consider all new thoughts today. The record of the achievements of two hundred years was easily recognized by Macaulay to be without parallel in the past, when he wrote these words: "Ask a follower of Bacon what the new philosophy, as it was called in the time of Charles the Second, has effected for mankind, and his answer is ready: It has lengthened life. It has mitigated pain. It has extinguished disease. It has increased the fertility of the soil. It has furnished new arms to the soldier. It has given new securities to the mariner. It has

*Delivered as an address March 11, 1909, before the Illinois Fuel Conference at the University of Illinois, Urbana.

spanned great rivers and estuaries with bridges of a form unknown to our fathers. It has guided the thunderbolt innocuously from heaven to earth. It has lighted up the night with splendor of day. It has extended the range of human vision. It has multiplied the power of the human muscles. It has accelerated motion. It has annihilated distance. It has facilitated intercourse, correspondence, all friendly offices, all dispatch of business. It has enabled man to descend into the depths of the sea, to soar into the air, to penetrate securely into the noxious recesses of the earth, to traverse the land in cars whirled along without horses, and the ocean in ships that run ten knots an hour against the wind.

These are but a part of its fruits and of its first fruits. For it is a philosophy that never rests, which has never attained, is never perfect. It law is progress. A point which yesterday was invisible is its goal today and will be its starting point tomorrow."

When these words were written no doubt there were many thinking people to whom this record seemed impossible of duplication, even if it did not to Macaulay.

And yet at that time the first practical steam engine had been used but little longer than the Bell telephone of today has been in practical use; the first steamboat was no older than electric lights now are; the Morse electric telegraph was as much a novelty as wireless telegraphy now is, and travel by railroad was but a few years in advance of the aerial navigation of today.

Antiseptics and anti-toxins were among Macaulay's invisible points and a demonstration of radio-activity would have been generally regarded as a manifestation of the Evil One.

Nearly all great scientific discoveries have been made by men who dreamed and experimented, rather than by those who were working solely for practical results; but their practical application largely has been made by the latter class. Sire Humphrey Davy invented a safety lamp, but the lamp has to be carried by the man who works in the mine and who must be taught how to use it with safety. Safety helmets have been invented by men versed in scientific knowledge, but the helmets must be worn by the heroes who risk their lives for their fellow men, and they must be trained in this use, for their own safety. The establishment of this Relief Station is a great humane work by men of science; but the success will depend upon the men who are to be trained in it. Only by unreserved and ungrudging cooperation of the practical and the scientific can it be hoped to secure those results which we all desire and hope to see.

For the mine owners of Illinois, I welcome and accept the proferred assitance in the discharge of our duty to humanity, and dare to hope that it may mark the beginning and be one of the important elements of a new era in the conservation of human life and happiness in the coal mines of our great state.

THE MINE RESCUE STATION AT URBANA.

A. C. YEHLING, E. E. '09.

Illinois next to Pennsylvania, is the greatest coal-producing state in the Union. It is appropriate, therefore, that Illinois should be deeply interested in the problems met in mine operation, and especially in those problems relating to the safety of the men employed. In connection with the Illinois Fuel Conference, held at the University, March eleven to thirteen, a Station, founded for the purpose of offering (sympathetic study of mine explosions) and systematic training of men for mine rescue work, was formally opened. The Urbana Station is the second institution of its kind in the United States, and is the first established at a University. It is to be maintained by the United States Geological Survey, together with the Illinois State Geological Survey, and the University of Illinois.

The "home" Station, at Pittsburg, has, since its establishment, been devoting the major portion of its time to the specific study of mine explosions—analyses of coals and gases. The Urbana Station will concentrate more of its attention upon the rescue of men overcome in mine disasters. During the visit of the mine operators and mining engineers to the Fuel Conference, Mr. R. Y. Williams, who is in charge of the Station, gave some very interesting demonstrations in the use of the new oxygen helmets and resuscitating apparatus.

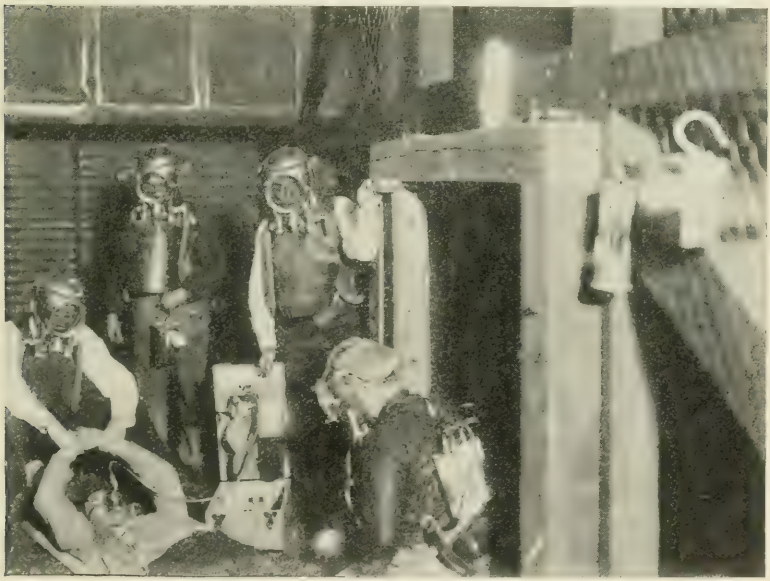
The equipment of the Station includes the most recent inventions, and it is surprising to a novice to discover the degree of perfection reached in some of these devices. A few of the pieces of apparatus may be named:

(1) Four Draeger Oxygen Helmets, and recharging apparatus
(2) One Draeger Resuscitating Case.
(3) Four Hubbel Electric Portable Safety Lamps.
(4) One Portable Orsatt Outfit for Quantitative Analysis of Mine Gases.
(5) One "Smoke Room."

The Oxygen helmets are constructed of metal, and look much the same as the helmets worn by deep-sea divers. There is not the necessity here for making the helmets heavy and water-tight, hence they are made to fit tightly only over the face, with just a small portion of the shell to cover the top of the head. A perfect "fit" for various sizes of faces is obtained by inflating a thin rubber lining, at the edges of the helmet; it is thus that the poisonous gases in the mine, following an explosion, are excluded from the face.

The fresh oxygen necessary to the wearer is supplied to the helmet through tubes leading from two small steel drums strapped to the back. These drums are about four inches in diameter and ten inches long, and contain oxygen at a pressure of about one-hundred and fifty atmospheres—over a ton to the square inch—sufficient in quantity to last two hours. A small pressure gage fastened on the breast of the wearer indicates the amount of oxygen in the drums at any time, and is also calibrated to read on another scale the number of hours the supply of oxygen should reasonably last. This allows the necessary precautions to be taken by the wearer in allowing time to return to the mouth of the mine for fresh recharging of the drums.

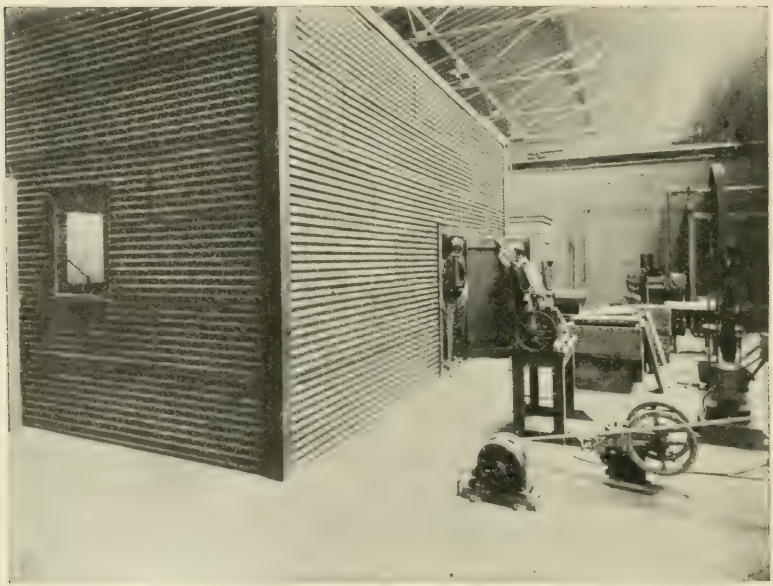
The reason for the great length of time which these small



Instruction in the Use of Rescue Apparatus.

quantities of oxygen will last may be explained: Common out-door air contains, roughly, 80% nitrogen, and 20% oxygen. The breath exhaled by a person contains, however, besides nitrogen and oxygen, about 5½% of carbon-dioxide, which is poisonous. With the Draeger, oxygen helmets the carbon dioxide is freed from the other portion of the breath, thus allowing continuous breathing of the same air—that is, with just sufficient oxygen added from the storage drums to give the necessary 20%. The carbon dioxide, passing through bottles of potassium hydroxide, which are strapped on the back with the oxygen drums, unites with that chemical, giving potassium carbonate.

To recharge the oxygen drums, they are connected to large storage drums, such as come directly from the factory, and with the valves opened, receive the compressed oxygen at the high storage pressure. The recharging requires very little time, so that a rescue force of men may work with very few interruptions after it has reached the scene of the explosion in the mine. The Hubbel portable safety lamps are constructed of aluminum, to give as little weight as possible; the light is supplied from a small incandescent lamp, running on current from a small storage cell. As an extra precaution a duplicate bulb and cell are provided in the lamp in case the first set should burn out. These Hubbel safety lamps are



The "Smoke Room," in which men are trained in rescue work.

so attractive that the Station operators have much to do while at a coal mine to see that they are not stolen.

Among the necessary equipment for a hasty call to any mine disaster is the Orsatt Outfit of chemicals for making analysis of the mine gases. The analyses are made before heavy reconstruction or rescue work is attempted. Samples of the mine gases are first obtained for various sections of the mine, and by submitting these samples to chemical tests on the spot the percentages of carbon-dioxide and carbon monoxide may be determined, and the safety of the mine known.

The "smoke room" is a gas-tight building, of dimensions

12′×25′×12′, located in the Mechanical Engineering Laboratory building. The interior is fitted up with heavy beams and low-passage-ways, similar to the construction of an actual mine. Sulphur may be burned in the room, producing conditions similar to those found after actual mine disasters. A dummy of a man offers an opportunity for practice at resuscitation of victims.

The men under training at the Station, after putting on their helmets and oxygen apparatus, enter the room, which is filled with the sulphur fumes. After being walked around the room, and over various obstacles, they finally arrive "at the scene of the disaster." There they practice at carrying the dummy about on the stretcher, resort to artificial respiration to resuscitate him, and are trained in other incidents of routine work. The practice of this sort is for the purpose of making the men accustomed to the helmets, so that any unexpected squeak or pinch will not frighten them.

Several mine operators and mine bosses have already taken advantage of the services offered by the Urbana Mine Rescue Station, and have taken training in the use of the new apparatus. The service is to be rendered gratuitiously; and it is hoped that the influence exerted by the Station in causing mine operators and inspectors to become interested in the economic value of these appliances as part of the normal equipment of mines may be extended over Illinois, Indiana, Kentucky, Missouri, Iowa, and other neighboring states.

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EDITORIAL.

"Smoke and the Public Health" may seem out of place as the title of an article in THE TECHNOGRAPH, but we believe a little consideration will convince the reader of its appropriateness. As our civilization grows more complex, the yield of the technical man is constantly broadening. Matters fifty years ago were decided by the Town Council or the state legislature with comparatively short discussion; now public questions are referred to experts and boards of examiners.

So the safeguarding of the public health has passed thru the stage of brief discussion and arbitrary action and is regarded as deserving careful investigation by trained experts. Not only doctors and scientists, but engineers, are called upon to subtract as much as is possible from the dangers surrounding the life of man.

Two great national movements of recent years have brought into prominence the work of the engineer. These are the agitation in favor of a great inland deep waterway, and the awakening to the need of conserving our national resources. In a broad way they both deal with the subject of conservation. In spite of America's great natural wealth, the time has come when strenuous efforts must be directed toward economy and efficiency of production in order that we shall not some day find our resources exhausted and our prosperity at an end. Probably the question of most importance to the public in the next decade will be this one of conservation.

As a specialist in manufacturing and transportation the engineer will necessarily have much to do with this subject of conservation. His opinion has come to have considerable weight, and the nature of the subjects gives him excellent opportunities to make his work of lasting public benefit. The greatest problems of the day are given to him for solution; the safety of public travel, improved methods of communication, pure water supply for our cities, the prevention of accidents in factories and mines, the transportation problem in congested centers, and the conservation of our natural resources.

No doubt there are fields as yet undeveloped in which the engineer will play as important a part as he does now in transportation or mining. Specialization is the order of the day, and in the next century the place of the engineer must be of increasing importance. He is the great industrial doctor, and his skill, his knowledge, and his professional honor are quite as important to the industrial world as are those of his physician to each individual.

The often-discussed question of making THE TECHNOGRAPH a quarterly or a monthly rises again this year. Aside from the question of finances, there is only one real difficulty:—that of lack of organization. Before a quarterly can be successfully published the effort should be made to unite more closely those interests behind THE TECHNOGRAPH. At present the Board is too far removed from the Societies and the Societies are too distinct and too loosely held together for that cooperation so desirable in such an undertaking as the publication of a quarterly.

The Board itself is little more than a name. The book has generally been published by the editor and the business manager, with such assistance as the other members could give. This is not because more assistanec was not offered, but because with the looseness of organization it seemed easier to go ahead and do things than to hunt up some one else. Greater division of work is easily possible, and would help in more ways than one. If the juniors on the Board could be given more responsibility under the seniors, a new year would not find the Board entirely unprepared for its work.

We confess this is largely our own fault, and the matter is given this much publicity only because a little more attention to THE TECHNOGRAPH by the Societies would encourage the Board to a better organization and greater effort.

During the second semester there has been formed at the University a section of the American Society of Mechanical Engineers. Fifty-four men applied for membership, and eleven faculty men were made honorary members. Dean W. F. M. Goss is the honorary chairman, and the other officers are as follows: President, W. F. Coleman; vice-president, F. E. Sperry; secretary, S. G. Wood; treasurer, D. Rugg.

THE ARCHITECTS' CLUB.

The officers of the Architects' Club for the first semester were: President, W. H. Schulzke; vice-president, H. S. Horner; secretary, Louise Pellens; treasurer, Ramon Schumacher. For the second semester they were: President, Ben Horn; vice-president, O. E. McBride; secretary, H. J. Rieger; treasurer, A. E. Bramhall.

THE ELECTRICAL ENGINEERING SOCIETY.

The officers of the society for the first semester were: President, P. M. Farmer; vice-president, E. D. Doyle; secretary, W. B. Worsham; treasurer, B. M. Beach; librarian, H. S. Thayer. For the second semester the following men served: President, C. S. Pope; vice-president, R. E. Doherty; secretary, B. C. J. Wheatlake; treasurer, E. H. Bailey; librarian, H. S. Thayer. For the first semester of next year H. M. Turner will be the president, and the new Technograph men are D. A. Pierce, '10, and Keene Richards, '11, E. D. Doyle, '10 remaining on the board from this year. During the first semester the society heard the following lectures:

The Electrification of the St. Clair Tunnel, by F. A. Sager; the Building of an Interurban Railway, by Prof. Matthews, of Purdue University; The Training of the Electrical Engineer, by L. A. Ferguson. During the second semester no lectures were given and only one meeting held.

MECHANICAL ENGINEERING SOCIETY.

The professional program carried out during this current school year was as follows: "Steam Turbines," by Prof. J. C. Thorpe, Assistant Professor of Mechanical Engineering; "Power Plants," by Mr. G. M. Brill, M. W. S. E., Consulting Engineer; "Indicators," by Prof. L. P. Breckenridge, head of the Mechanical Engineering Department; "The Engineer, His College Training, Is it Satisfactory?" by Prof. F. D. Crawshaw, Assistant Dean of Engineering; "Cranes," by Prof. O. A. Leutwiler, Assistant Professor of Mechanical Engineering; and "Apprentice Systems," by Mr. E. I. Wenger of the department of Railway Engineering and Mr. K. G. Smith of the department of Mechanical Engineering.

In addition to this, two student programs worthy of note were given. The first, on "Air Brakes," which a complete equipment for an engine and one freight car was in actual operation, was given by H. C. Krannert, '12, W. R. Hanes '10, I. S. Wood, '10, and W. F. Coleman, '10. The second, on "Pneumatic Tools" was given by J. C. Parmalee, G. A. Cooper, W. M. Haskell, and F. E. Sperry all of the Junior class. Several section models of tools were imported from Aurora for this lecture. Since the inauguration of student programs the membership of the society has more than doubled.

An important change in the constitution was made the last meeting in January and provided that the president and treasurer be elected for two semesters, the term to commence with the second semester. This was done to prevent the loss of records during the summer months and to have good programs the first semester when it is easier to obtain large audiences. The first officers to be elected under this regime were D. C. Patton, President, and I. B. Altekruse, Treasurer.

In the early part of the year a smoker was held in the new Y. M. C. A. building and an enjoyable time was had by all present. Another one is to be given the thirty-first of May in Hessel Hall in Champaign and is to be in the nature of a farewell to Prof. Breckenridge. A large and enthusiastic crowd is expected.

CIVIL ENGINEERS' CLUB.

The C. E. Club for 1908-1909 elected R. C. Wagner president; C. S. Stewart vice-president; W. T. McClenahan, secretary, all '09 men, and C. E. Beveridge, '10, treasurer. President Wagner appointed R. O. Beck chairman of the program committee who at once began a vigorous campaign for speakers. It seemed impossible to get outside men until the months of January and February. During these months the club listened to addresses by Mr. Jordan of the Burlington. C. W. Boynton of the Universal Portland Cement Co., W. H. Findley, W. D. Taylor of the Chicago & Alton, P. E. Green and Mr. Henry of the Engineering News. These lectures were all well attended, in some cases the room was crowded so that many had to stand.

For the second semester R. O. Beck was elected president, K. H. Talbot, vice-president, H. Burgess, secretary, A. H. Hunter, treasurer, and G. W. Russell sergeant-at-arms. All of these men are '09 men. The membership numbers something over ninety men. The strange part of the membership is that the majority are drawn from the senior class.

The culb held its annual smoker in Hessell Hall which was very well attended. D. G. Bevis had charge of the affair. Prof. Baker, Dufour, Malcom, Brook and Sanborn each gave a short talk. Several of the seniors also were called on.

CANDIDATES FOR THE DEGREE OF BACHELOR OF SCIENCE.

DEPARTMENT OF CIVIL ENGINEERING.

Henry Conrad Ackemann.....Comparative Tests of Railway Tie Plates.

Frank Boyd Baldwin.....A Recording Device for Indicating (a) The Flow of Water in Pipes, (b) The Speed of Boats.

Frank Fairwell Beeby.....A Comparison of the Efficiencies of a Two-Hinged and a Three-Hinged Steel Arch.

Rodney Linton Bell.....Tunnel Timbering and Lining.

Daily George Bevis.....An Investigation of the Engineering and Economic Phases of the Reduction to a Specific Ruling Grade of the Illinois Central Railroad by the Method of Reduction in Place.

Charles Emery Bressler, Jr.....Tests of Concrete and Reinforced Concrete Wall Footings.

Avery Brundage .....Detailed Study of Specifications for Steel Bridges.

George Francis Burch.....Tests of Plain Concrete Columns.

Harry Holdridge Burgess.....Yard Fire Protection of the University of Illinois Buildings.

Hervey Richey Cawood.....Detailed Study of Impact in Steel Bridges.

Ray Arthur Collins.....Effect of Moving Loads on Highway Bridges.

Frank Samuel Cook.....Influence of Lime on the Permeability of Concrete.

George Delwin Corwine.....Tests of Longitudinal Reinforced Concrete Columns.

Fred Dwight Danford.....Wood Block Pavements.

Homer Roscoe DeWitt.....Tests of Logitudinally Reinforced Spiral-hooped Concrete Columns.

Wilbur Lawrence Dunn.....Tests of Concrete Columns Reinforced with Latticed Steel Angles.

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UNIVERSITY OF ILLINOIS
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1910

TO ERNST JULIUS BERG,
WHO, DURING THE BRIEF PERIOD SINCE HIS CONNECTION WITH
THE UNIVERSITY, HAS WON THE ESTEEM OF
EVERY ENGINEERING STUDENT, THIS
VOLUME OF THE TECHNOGRAPH
IS RESPECTFULLY DEDICATED.

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Ernst Julius Berg

THE TECHNOGRAPH

No. 24 UNIVERSITY OF ILLINOIS 1909-1910

ERNST JULIUS BERG.

Dr. Ernst Julius Berg was born in Sweden in January, 1871. He graduated from the Royal Polytechnical Institute of Stockholm in Mechanical Engineering in 1892 and a year later came to the United States. For the past seventeen years he has been associated with the General Electric Company, which company he left in September of last year to assume his duties as Professor of Electrical Engineering of the University of Illinois. As a representative of the General Electric Company, Dr. Berg designed and personally supervised the erection of the first rotary transformers which were installed in the City of Chicago a dozen or more years ago, and he has since had his part in the development of the various forms of electrical machines which have made up the product of this company. In his capacity as an expert advisor for the General Electric Company, he has been concerned with the great works at Schenectady and also with those at Lynn, Massachusetts. His business has many times taken him abroad for consultation upon technical matters with various foreign representatives of the company. During the last three years, as a diversion from his more formal duties, he has served as a special lecturer of Union University of Schenectady, and he received from that institution in 1909 the honorary degree of Doctor of Science. Dr. Berg understands English, German, French, Swedish, Norwegian, and Danish. His scientific contributions are numerous and of high value. His book on "Electrical Energy" and his var-

ious papers before the American Institute of Electrical Engineers are entitled to special mention. Dr. Berg's experience in designing, building, installing, and operating electrical machinery permits him to deal with the more practical problems of his profession with a degree of enthusiasm that is well-nigh irresistible, and the fact that he has achieved success in advancing the more theoretical phases of electrical engineering is inspiring to those who are interested in the development of problems through mathematical processes. As a close personal friend and for many years a coworker with the celebrated Dr. Steinmetz at Schenectady, Dr. Berg has kept himself in touch with the best thought in his field and has had a part in its development. Dr. Berg began his work at the University in November, and in the brief period since that date has completely won the friendship and esteem of the students of his department and of his associates of the Faculty.

W. F. M. Goss,
Dean of the College of Engineering.

THE CONDITION AND ACTION OF STEAM IN TURBINES.

ERNST J. BERG, Sc. D.
Professor of Electrical Engineering.

In the preceeding number of the Technograph, Professor Thorpe gave some very interesting results of tests on Curtis turbines. These tests showed in a general way the characteristics of turbine operation, the effect of change of initial pressure, superheat, vacuum, etc.

Having been to a slight degree instrumental in the development of this type of turbine, the writer will endeavor in this article to show briefly the practical considerations that enter into its design.

The available energy of steam is, as is well known, expressed by the following relation:

Ft. lbs. per pound of steam $= 778\ [H_1 + C_p t_1 - (q_2 + xr_2)]$ where:

$H. =$ total heat at pressure p_1.

$C_p =$ specific heat of superheated steam at pressure p_1.

$t_1 =$ superheat in degrees F. at pressure p_1.

$q_2 =$ heat of liquid at pressure p_2.

$x_2 =$ quality of steam at pressure p_2.

$r_1 =$ latent heat at pressure p_1.

$r_2 =$ latent heat at pressure p_2.

The quality of steam x_2 can be calculated since the entropy is the same before and after expansion.

Entropy of superheated steam $=$

$$C_p \log_e \frac{T_1 + t_1}{T_1} + \frac{r_1}{T_1} + \phi_1.$$

Entropy of moist steam $=$

$$\frac{x_2 r_2}{T_2} + \phi_2.$$

In these equations, T_1 and T_2 are the absolute temperatures of saturated steam at pressures p_1 and p_2 respectively

$\phi_1 =$ entropy of water at pressure p_1,

$\phi_2 =$ entropy of water at pressure p_2.

EXAMPLE:—To illustrate the application of these formulae, the substitutions necessary to find the available energy per pound of saturated steam when expanding adiabatically from 175 lbs. absolute pressure to one pound (about 28 in. vacuum) are shown below.

We have:

$$\frac{r_1}{T_1}+\phi_1=\frac{x_2 r_2}{T_2}+\phi_2$$

whence

$$x_2=\frac{T_2}{r_2}\left(\phi_1-\phi_2+\frac{r_1}{T_1}\right)$$

$$=\frac{461+102}{1043}\left(.53-.134+\frac{851.6}{461+370.5}\right)=0.766$$

Thus moisture $1.-.766.=23.4$ per cent.

The available energy in ft. lb. =

$$778\ [1194.9-(70.1+.766\times 1043)]=253{,}000.$$

It is interesting to note that the moisture at the low pressure is 23.4 per cent, if all available energy is converted into mechanical work. No engine can, however, have 100% efficiency, therefore, some energy is wasted internally as heat, which heat evaporates some of this moisture so that in reality the per cent moisture entering the condenser is considerable less than 23.4%. The higher the efficiency the nearer the value of 23.4% would be approached.

Assuming, for instance, that the efficiency of a single stage turbine operated under the conditions given above is 70%. The energy available for evaporation (neglecting losses by radiation, which are small) is $.30\text{x}253{,}000=75{,}900$ ft. lb. The latent heat at one pound absolute pressure is 1043.1, hence, to evaporate one pound $1043.1\text{x}778=812{,}000$ ft. lb. are required. Therefore, with 75,800 ft. lb. we evaporate .0935 lb. The moisture is therefore:

$$.234-.0935=.1405,\text{ or } 14.05\%.$$

In a multi-stage machine, with a given efficiency of each individual stage, the joint efficiency is higher than the individual efficiency. For instance, with a four-stage turbine operated with initially dry saturated steam at 175 lb. absolute pressure and 28″ vacuum, if the efficiency of each stage

is 70%, and the work in each stage is approximately the same, the following condition of moisture in the different stages exists:

In the first stage (at 63 lb. pressure) 4% moisture;
In the second stage (at 19.5 lb. pressure) 7.8% moisture;
In the third stage (at 5 lb. pressure) 11.5% moisture;
In the fourth stage (at 1 lb. pressure) 14.8% moisture;

Comparing this with the moisture given in the previous case of 14.1%, we see that the four-stage machine has converted more steam to water or has abstracted more energy. The efficiency corresponding to this moisture is, as can readily be determined from the above method, 72.4%.

There is, therefore, an apparent gain in using many stages. It might be well, however, to mention that the gain, although considerably more between a one-stage and a four-stage turbine, is proportionately very much less as the number of stages is increased. It is approximately 1.5 % in going from four to twenty stages.

This gain, however, cannot be fully taken advantage of, since with increased number of stages other difficulties appear, as for instance steam leakage around diaphrams, etc.

To illustrate the dependence of moisture on the efficiency, the following tables have been prepared for a single stage and four-stage turbine.

Single Stage Turbine:

Pressure of saturated steam	175 lb. abs.			
Exhaust pressure	1 lb.			
Per cent eff. of turbine	100.	70	50	30
Per cent moisture in exhaust	23.4	14	7.7	1.4

Single stage turbine:

Initial pressure.....	175 lb. abs.			
Condition of steam.....	200° F. superheat			
Exhaust pressure.....	1 lb. abs.			
Per cent eff. of turbine	100.	70.	50.	30
Per cent moisture of superheat	17.6	7.05	.05	144° sup.

Four-stage turbine:

Pressure of saturated steam....	175 lb. abs.
Exhaust pressure.....	1 lb.

Per cent. eff. of each stage	80	70	60	50	40	30
" " moisture in 1st stage	4.9	4	3	2	1.1	$.0_1$
" " " " 2nd "	9.6	7.8	6.1	4.3	2.6	$.0^8$
" " " " 3rd "	14	11.5	9	6.5	4.1	1.6^8
" " " " 4th "	18	14.8	11.8	8.6	5.5	2.4

Four-stage turbine:

Pressure.....175 lbs. ab.
Superheat.....200°
Exhaust pressure.....1 lb.

Per cent. eff. of each stage	80	70	60	50	40	30
" " moisture or sup. 1st stage	84°	106°	127	148	172°	192° F.
" " " " " 2nd "	2%	0	44°	85°	126	168° F.
" " " " " 3rd "	7%	3%	.4%	20	80°	136° F.
" " " " " 4th "	12%	8.4%	5%	2%	35	108° F.

It is interesting to note that with 200° superheat and dry exhaust the efficiency cannot be higher than about 45%.

It is unfortunately very difficult to determine the true conditions of the steam in the exhaust. Practical experience has shown that it is almost impossible to get a true sample.

It is evident, however, that if there were any practical ways of obtaining the percentage of moisture in the exhaust of a turbine the efficiency could be directly found.

In the larger Curtis turbines, the steam enters the first stage nozzles at boiler pressure at all loads, (neglecting the drop in pressure in the high pressure steam mains).

In the smallest size and indeed in all turbines of the "Parsons" or reaction type, there is at some loads a throttling of the steam. The effect of this throttling is not insignificant, but on the contrary it represents a considerable loss of useful energy, although at first sight it would seem small considering that there is evidently practically no loss from radiation at the valve.

To illustrate this loss it will be assumed that the boiler gives saturated dry steam at 175 lb. absolute pressure, and that by throttling, the pressure is reduced to 100 lb. abs.

The specific heat of superheated steam is not definitely known, but will be assumed as .5. We have, therefore, assuming no loss by radiation:

Total heat of saturated steam at 175 lb. = total heat of saturated steam of 100 lb. + $.5\,t_1$ where t_1 is the amount of superheat.

The total heat at 175 lb. sat. steam is....1,194.9
The total heat at 100 lb. sat. steam is....1,181.9
The difference is 13

$$\text{Thus, } .5\ t_1 = 13 \text{ and } t_1 = 26^\circ \text{ Fah.}$$

From the equations given previously, it can be determined that the available energy of saturated steam between 175 lb. and 1 lb. is 253,000 ft. lb. and the available energy of superheated steam at 100 lb. and 26° superheat is 228,400 ft. lb., therefore, the ratio is,

$$\frac{228{,}400}{253{,}000} = .902,$$

or 90.2% only is available at the lower pressure.

In this connection it may be of interest to discuss the use of the *throttling calorimeter*, and the bearing the uncertainty of specific heat of superheated steam has on the deductions.

It will be assumed that the calorimeter is connected to the atmosphere and that the initial pressure is 175 lb. abs.; the condition of the steam is unknown, and the temperature of the superheated steam at atmosphere pressure is 262° Fah., thus 50° superheat.

Since the total heat is assumed the same at the two pressures, we get:

Total heat at 14.7 lb. saturated steam $+ C_p \times 50 =$ total heat of saturated steam at 175 lb. + heat of the liquid.

Let x be the percentage steam, thus $1 - x =$ percentage liquid.

The liquid heat at 175 lb. pressure is 343.3, thus we get:

$$1{,}146.9 + 50\ C_p = 1{,}194.9\ x + 343.3\ (1 - x),$$

or

$$x = \frac{803.6 + 50\ C_p}{851.6}$$

For $C_p = .5$ we conclude a moisture of 2.75%
For $C_p = .6$ we conclude a moisture of 2.1%

From the equation it is readily seen that with saturated exhaust the initial moisture may be 5.7% or more.

The calorimeter, therefore, cannot record more than 5.7% moisture under this pressure condition. In reality it

is limited to a considerably smaller percentage on account of the error in temperature deduction, difficulties of getting true samples of the steam when loaded with much moisture, etc.

Efficiency of Turbines.

The best way to determine the efficiency is to note the pressure and temperature readings of the steam supplied to the turbine, the amount of condensed steam per hour, the exhaust pressure and the electrical output of a generator connected thereto.

If it is desired to get only the combined efficiency of the generator and turbine the determination is simple. It is only necessary to calculate from the formula given previously the available energy, and to convert the foot pounds into kilowatt hours.

One kilowatt hour is equivalent to 2,654,000 ft. lb. Assuming then that, for instance, the available energy between the pressure ranges is 253,000 ft. lb. the theoretical water rate per kilowatt hour is obviously

$$\frac{2{,}654{,}000}{253{,}000} = 10.5 \text{ lb. per hour.}$$

If the test gives 15 lb., we can conclude that the efficiency is $\frac{10.5}{15}$ or 70%. The generator efficiency may be 95%, therefore, the turbine efficiency is 73%. In general the efficiency is

$$\Phi = \frac{\text{theoretical water rate}}{\text{observed water rate.}}$$

The theoretical water rate is 2,654,000 divided by the available energy per pound of steam between the correct pressure ranges and at the correct temperature.

For the sake of convenience the values of theoretical water rate over a wide range of pressures and superheat are tabulated below. From the tables it should be possible to interpolate for any other steam condition that is likely to be used in practice.

Theoretical water rate for various pressures, vacuum and superheat:

Theoretical Water Rate

Superheat Initial Pressure absolute	Inches Vac.	Theoretical Water Rate				
		200°	150°	100°	50°	0°
215 lb.	29	8.45	8.7	8 95	7.2	9.45
"	28	9.	9.25	9.5	9.75	10.
"	27	9.5	9.75	10.05	10.3	10.55
"	26	9.9	10.2	10.50	10.8	11.11
"	20	11.65	12.07	12.50	12.87	13.25
"	10	13.65	14.15	14.65	15.15	15.65
"	0	15.25	15.8	16.4	16.9	17.4
" 2 lb.	bk. pres.	15.05	16.07	17.1	17.6	18.2
200 lb.	29	8.55	8.8	9.05	9.32	9.6
"	28	9.1	9.4	9.7	9.95	10.2
"	27	9.6	9.9	10.2	10.45	10.75
"	26	10.	10.32	10.65	10.97	11.3
"	20	11.75	12.4	12.8	13.2	13.6
"	10	14.	14.5	15.05	15.57	16.
"	0	15.6	16.2	16.9	17.4	17.9
" 2 lb.	bk. pres.	16.3	16.9	17.5	18.	18.7
175 lb.	29	8.75	9.02	9.3	9.55	9.8
"	28	9.35	9.62	9.9	10.18	10.45
"	27	9.85	10.15	10.45	10.75	11.05
"	26	10.3	10.65	11.	11.3	11.6
"	20	12.4	12.82	13.25	13.65	14.05
"	10	14.65	15.77	15.70	16.25	16.8
"	0	16.4	17.35	18.3	18.6	18.9
" 2 lb.	bk. pres.	17.1	17.75	18.4	19.1	12.8
165 lb.	29	8.85	9.12	9.4	9.63	9.86
"	28	9.45	9.72	10.	10.3	10.6
"	27	10.	10.32	10.65	11.	11.3
"	26	10.5	10.85	11.2	11.55	11.9
"	20	12.6	13.05	13.5	13.9	14.3
"	10	14.9	15.05	16.1	16.57	17.05
"	0	16.85	17.52	18.2	18.75	19.3
" 2 lb.	bk. pres.	17.6	17.3	19.		20.3
140 lb.	29	9.12	9.37	9.65	9.9	10.2
"	28	9.75	10.05	10.35	10.65	10.95
"	27	10.3	10.62	10.95	11.28	11.62
"	26	10.85	11.20	11.55	11.95	12.3
"	20	13.1	13.6	14.1	14.6	15.1
"	10	15.8	16.4	17.	17.6	18.2
"	0	17.9	18.6	19.3	20.	20.65
" 2 lb.	bk. pres.	18.6	18.95	20.3	21.	21.8
125 lb.	29	9.35		9.88		10.4
"	28	10.03		10.6		11.2
"	27	10.70		11.3	11.6	11.9
"	26	11.23		11.9		12.55
"	20	13.65		14.6		15.50
"	10	16.50		17.7		18.98
"	0	18.90		20.4		21.80
" 2 lb.	bk. pres.	19.85		21.6		23.1
100 lb.	29	9.77		10.25		10.89
"	28	10.50		11.16		11.72
"	27	11.2		11.9		12.50
"	26	11.83		12.65		13.23
"	20	14.70		15.80		16.65
"	10	18.		19.45		20.7
"	0	20.9		22.28		24.25
" 2 lb.	bk. pres.	22.15		24.25		25.82
Atmos. (14.7 lb)	29	15.4		16.65		17.7
" "	28	17.65		19.1		20.4
" "	27	20.		21.8		23.3
" "	26	22.40		24.5		25.4
10" Vac. (10 lb)	29	17.25		18.8		20.2
	28	20.20		22.1		24.2
	27	23.50		25.8		28.6
	26	26.95		30.		33.

It is evident from these tables that there is a very considerable gain in water rate by high vacuum and high superheat, and since the boiler plant is directly dependent upon the amount of water required, it is evident that there is a considerable saving in initial cost of the power plant.

It must, of course, not be forgotten that high vacuum is only possible with relatively low temperature of the cooling water, and that the amount of cooling water is necessarily considerably greater than that with low vacuum. The condenser itself is also considerably larger than for lower vacuum. However, the saving by reduced boiler installation more than compensates for the cost of the larger circulating pumps, condenser, etc.

The great saving by the use of high vacuum is, however, in the coal consumption. The per cent saving in coal corresponds practically to the gain by increased vacuum in the water rate. So, for instance, assuming the same efficiency of the turbine when operating at 27″ and 28.5″ vacuum the gain in water rate at average commercial initial pressure is 9.5%, and 9.5% in water means substantially a saving of 9.5% in coal.

The gain in theoretical water rate by superheat is also considerable, being approximately 6% per 100°, in reality due to the reduced rotation losses on account of the lesser water in the steam, the gain is still greater, being about 8% per 100°.

This gain in water rate, however, only slightly affects the coal consumption. As an instance, the relative coal consumption for a turbine operated at 200 lb. absolute initial pressure with dry saturated steam and 28″ vacuum, and another with same pressure but 100° superheat will be determined.

The total heat per pound of saturated steam at 200 lb. pressure is 1198.3, the heat corresponding to 100° superheat (assuming C_p as .5) is 50, thus the increase in heat with superheat is

$$\frac{50}{1198.3} = .0417 \text{ or } 4.17\%$$

The available energy in the superheated steam between 200 lb. and 1 lb. is 275,200 ft. lb. In saturated steam it is

261,000 ft. lb., thus, the increase in available energy is 5.37%, while the gain in coal is $5.37\% - 4.17\% = 1.2\%$. As stated above, the gain in water rate is considerably greater than corresponds to the gain in available energy and is about 8%, hence in practice the gain in coal by 100° superheat is $8 - 4.17$ or 3.8%. In this calculation it has been assumed that the flue gases in both cases leave at the same temperature, and that the thermal efficiency of the boiler in one case and boiler with superheat in the other is the same. In all probability, this is not quite the case, nevertheless there is a decided gain.

The reciprocating engine, especially when new and properly adjusted, converts the energy of steam to mechanical energy with high efficiency. This is particularly so when operating non-condensing, or with moderate vacuum only. It must be remembered that high efficiency does not mean low water rate in general, but low water rate, considering the energy in the steam delivered to the engine. For instance, an engine operating non-condensing with initially dry steam of 175 lb. abs. pressure and an efficiency, including generator, of 80% would have a water rate of 23.6 lb. per kilowatt hour. Another engine, operating with same initial pressure and 28″ vacuum and taking 17.5 lb. of water, would have an efficiency of 60%.

Due to the number of large cylinders, the cylinder condensation, etc., it is evident that the low pressure part of the steam engine is not as efficient as the high pressure part. In the steam turbine, due to the higher rotation losses in the part which has high pressure, the conditions are reversed, and the low pressure stages work, as a rule, with higher efficiency than those of higher pressure.

The reciprocating engine can have higher efficiency than the turbine at high pressures, the turbine higher efficiency at low pressures. An excellent combination is, therefore, *a high pressure reciprocating engine in conjunction with a low pressure turbine*. This combination is the more attractive from the central station point of view, since it does not involve discarding the installed equipment, but only the addition of new apparatus, as the load requires, which apparatus is much cheaper than new high pressure turbines or reciprocating engines with their boilers. This arrangement also reduces

very materially the coal consumption per kilowatt generated.

Mr. Barrus, in his book on engine tests, shows that ordinarily condensing effects a saving of only 25% in water rate in compound engines, and 17% in single cylinder engines.

Based upon these figures and certain assumptions of efficiency, it is possible to make a very instructive analysis of the gain that can be made by the installation of low pressure turbines.

While new and properly adjusted, the efficiency of the compound engine operating at atmospheric exhaust is very high, perhaps 90%. With ordinary care, however, the efficiency cannot be maintained at this value, but it averages probably 80%, which value represents about 75% efficiency when the losses of the electric generator are included.

The water rate of such a unit operating with initially saturated steam at a pressure of 175 lb. absolute is $\frac{18.9}{0.75}$ $= 25.2$ lb. per k. w. hour (see table). At 28.5 inches vacuum, according to Mr. Barrus, we can expect a water rate of $0.75 \times 25.2 = 18.9$ lb. which corresponds to an efficiency of $\frac{10.12}{18.9} = 53\%$ (see table and interpolate between 28 and 29 inches vacuum).

The available energy between 175 lb. pressure and atmospheric exhaust is 139,500 ft. lb. The energy converted per lb. of steam is $0.75 \times 139{,}500 = 104{,}000$ ft. lb. The available energy between 175 lb. pressure and 28.5″ vacuum is 262,000 ft. lb.; hence the energy converted is $0.53 \times 262{,}000 =$ 139,000 ft. lb. Thus while operating condensing, the part of the steam engine unit which converts low pressure steam to electrical energy supplies only $139{,}000 - 104{,}000 = 35{,}000$ ft. lb. of steam.

Due to the internal losses and the re-evaporation of part of moisture incidental thereto, the steam contains practically 8.9% moisture at atmospheric pressure. The available energy of each pound of mixture of steam and water expanded to 28.5″ vacuum is readily found to be 130,900 ft. lb. Hence the efficiency of the low pressure part of the steam engine cycle is only $\frac{35{,}000}{130{,}900} = 26.7\%$

Depending upon the size, of course, the efficiency of a low pressure turbine set might be from 60 to 70%. Assuming as a very conservative mean value 65%, it is evident that we can, for the same amount of steam, in one case convert 130,900 ft. lb. to 35,000 ft. lb. useful work; in the other to 85,200 ft. lb. useful work, or the total amount of useful energy in the case of the compound engine is

$$.75\text{x}139{,}500 + .267\text{x}130{,}900 = 139{,}000$$

in the latter case

$$.75\text{x}139{,}500 + .75\text{x}130{,}900 = 202{,}800$$

Thus, the low pressure turbine enables us to increase the output 46%, using the same amount of steam in both cases.

At overloads on the steam engine, the efficiency is usually very considerably lower than at full load, so that it is undesirable to operate them at such loads. With the combination of a low pressure turbine, it is, however, not serious, since the turbine has a very uniform efficiency over a wide range of loads.

It can be shown in a similar way that with 50% more than the normal amount of steam, the combination gives more than twice as much output as the engine.

REGARDING THE ACTION OF THE STEAM IN THE TURBINES.

Broadly speaking, in the impulse type, as first represented by DeLaval, and later modified by Curtis the energy of the steam is converted to velocity in the nozzles and there is no expansion of the steam in the wheels. In the reaction type, the steam is usually expanded in the stationary as well as the moving elements.

In the original DeLaval turbine, which had one wheel only, the steam velocities and, therefore, the bucket and wheel velocity, was very high. For instance, the theoretical steam velocity when such turbine is operating non-condensing, found from the relation between energy and velocity, is

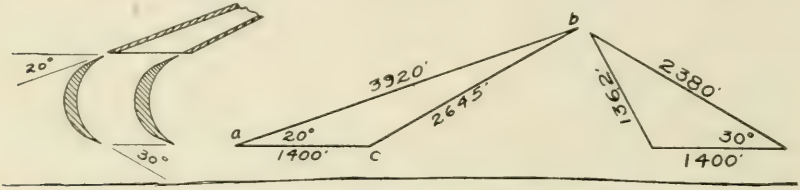
$$v = \sqrt{2 \times 32.2 \times \text{available energy}}$$

$$= 8\sqrt{\text{available energy}},$$

In this case it is $8\sqrt{139{,}500} = 2990$ feet per second. If operated at 28″ vacuum the available energy is 253,000 ft. lb. and $v = 4020$ ft. per second.

By a very careful construction DeLaval was able to use as high a bucket speed as 1400 feet per second.

Assuming a speed of 1400 feet, a nozzle loss of energy of 5%, and a loss in the wheel of 10% of the velocity, a nozzle angle at 20°, and a leaving angle of the bucket of 30°, we get the following diagram:



a-b is the velocity of the steam as it leaves the nozzle. Its value is

$$v = 8\sqrt{.95 \times 253{,}000} = 3920 \text{ ft. per sec.}$$

a-c is the bucket speed = 1400 ft. per sec.

b-c is the relative velocity of the steam as it enters the wheel, it is 2645 ft. per sec. The relative velocity as it leaves the bucket is then according to the loss assumption 2380 ft. per sec., therefore, the velocity rejected into space as seen is 1362 ft. per sec.

Under these assumptions then we have the following: Loss in the nozzle:

$$.05 \times 253{,}000 = 12{,}650 \text{ ft. lb.}$$

Loss in the wheel 20,600 ft. lb., and rejected energy = 28,800 ft. lb. making 62,050 ft. lb. Therefore, the bucket efficiency which corresponds to indicated efficiency with engines is

$$\frac{190{,}950}{253{,}000} = 75.5\%$$

To overcome the difficulties connected with high rotative and linear speed, such as are necessary for good economy in the DeLaval turbine, *Curtis* introduced the multi-stage type and the use of two or more wheels in each stage. This type can most readily be understood by considering each complete turbine as made up of a number of smaller turbines placed in series. The pressure distribution is governed by the size of the exhaust opening in each section, which opening, as a rule, forms the nozzles for the next section.

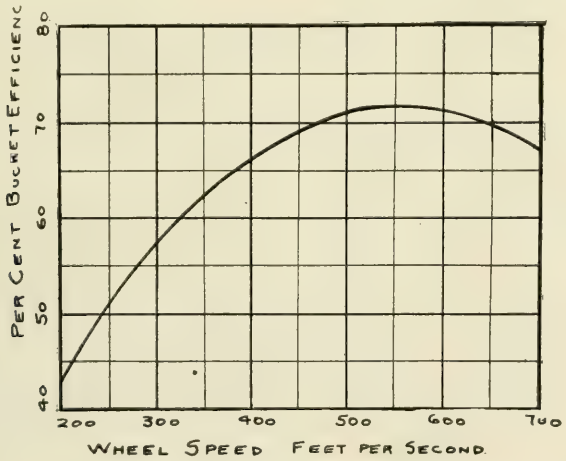
Depending upon the pressure in each stage, the work per stage varies. With the same work per stage, in a four stage turbine operated with initially dry saturated steam at 175 lb. abs. pressure and 28″ vacuum, the available energy of each stage should be:

$$\frac{253{,}000}{4} = 63{,}250 \text{ ft. lb.}$$

The shell pressures corresponding to this available energy are 63 lb., 19.6 lb., 5 lb., and 1 lb. abs., respectively, for the first, second, third and fourth stage. Thus, for instance, in the nozzles leading to the first stage the steam is expanded from the initial pressure of 175 lb. abs. to 63 lb. abs. Neglecting any losses in the nozzles the steam velocity as it leaves the nozzle at each stage is

$$v = 8\sqrt{63{,}250} = 2{,}015 \text{ ft. per sec.}$$

The relation between bucket efficiency (which corresponds to the indicated efficiency in the engine) and the bucket speed for this available energy is shown in the curve given below.



FOUR STAGE TURBINE, TWO WHEELS PER STAGE
AVAILABLE ENERGY PER STAGE 63250 FT. LBS.

It is evident that little is gained by a higher wheel speed than 500 ft. per second. Indeed the best results would be obtained, in all probability, at about 480 ft. per sec. since the

rotation loss which, with the bucket efficiency governs the shaft efficiency, increases very rapidly with the speed.

The *size of the nozzles and the expansion ratio* is governed by the flow of steam through orifices. As long as the pressure at the nozzle end is less than 58% of the initial pressure and the steam is dry and saturated, Napier's law $F = \frac{p_1 a_1}{70}$ or Grashof's law $F = \frac{0.97 \; p_1 \; a_1}{60}$ give results which closely agree with observed values.

Of the two laws, Grashof's seems, however, preferable, at least at low pressures, where Napier's law gives values of flow somewhat smaller than the actual. For instance, whereas the two laws agree within about 2% for pressure ranges from 80 to 200 lb. with a pressure of 15 lb., Napier's law gives values about 7% low and at 5 lb. 11% too low.

Napier's law has the great advantage of simplicity and is, therefore, preferable and can be used if a constant is applied, which depends upon the initial pressure.
We can write:

$$F = k \frac{p_1 \; a_1}{70}$$

where

F = flow of saturated steam in lb. per second.
p_1 = initial pressure in lb. abs.
a_1 = throat area in square inches.
k = constant = .995 for p_1 = 200 lb. abs.
= 1. for p_1 = 175 lb. abs.
= 1.01 for p_1 = 120 lb. abs.
= 1.02 for p_1 = 85 lb. abs.
= 1.03 for p_1 = 62 lb. abs.
= 1.04 for p_1 = 47 lb. abs.
= 1.06 for p_1 = 25 lb. abs.
= 1.08 for p_1 = 13 lb. abs.
= 1.12 for p_1 = 3.5 lb. abs.

The flow with superheated steam is reduced 6.5% for each 100° F. Thus, the equation becomes:

$$F = k \frac{p_1 \; a_1}{70} (1 - .00065 \; t_1)$$

where t_1 is the number of degrees superheat.

With moist steam the flow is increased approximately inversely as the square root of the quality x.

The general equation of steam flow therefore when $p_2 \leq 58p_1$, whether the steam is superheated, saturated, dry or moist, can be closely expressed as:

$$F = k \frac{p_1 a_1 (1 - .00065 t_1)}{70 \sqrt{x}}$$

As an example let

Initial pressure $p_1 = 100$ lb. abs.
Final pressure $p_2 = 50$ lb. abs.
Sup. $t_1 = 100°$ F.
Area $a_1 = 1$ square inch.

We have then.

$k = 1.015$, and $x = 1$.

$$F = \frac{100 \times 1 \times 1.015 \times .935.}{70} = 1.35 \text{ lb. per sec.}$$

With saturated steam the flow would have been

$$F = \frac{100 \times 1 \times 1.015}{70} = 1.45 \text{ lb. per sec.}$$

And with steam of 3% moisture the flow would be

$$F = \frac{100 \times 1 \times 1.015}{70 \sqrt{.97}} = 1.48 \text{ lb. per sec.}$$

When the difference of pressure is less, that is, when $p_2 > .58p_1$, the flow through a given orifice is less than given above and changes with the shape of the nozzle.

Grashof gives the following formula for saturated:

$$F = \frac{k_o \, p_1 \, 0.97 \, a_1}{60}$$

Where

$k_o = 1$ for $\frac{p_2}{p_1} = .58$
$= .9$ " $= .76$
$= .8$ " $= .83$
$= .7$ " $= .88$
$= .6$ " $= .915$
$= .5$ " $= .945$
$= .4$ " $= .955$
$= .3$ " $= .985$

This formula has been verified by Gutermuth when a non-expanding nozzle was used. With a nozzle having expansion he found, however, the flow to be somewhat greater.

Having determined the velocities of the steam in the various paths, and from steam tables the volume, we can, of course, readily proportion the actual dimensions of the buckets.

The nozzle throat area, that is, the smallest area of the nozzle, is found from the equation of the flow of steam.

The largest area of the nozzle governed by the expansion ratio, is determined from the same equations, taking account, of course, of the fact that almost always a considerable part of the steam is converted into water by the expansion in the nozzle, and, therefore, the area is less than would be the case if the exhaust were dry.

Other important features enter, of course, into the design but unfortunately these cannot be explained briefly or by equations. Such items are the rotation loss, the necessary practical clearances around the wheels, the effect of highly polished nozzles and wheels, etc. These details must be studied experimentally, not only with each type of turbine, but with different sizes of the same type.

THE EROSION OF TURBINE BLADES.

K. J. T. EKBLAW, B. S. IN M. E., '09.
Instructor in Farm Mechanics.

Practically the only deterioration occurring in a steam turbine, that can effect the steam consumption to any appreciable degree, comes from the cutting action of the steam or water upon the blades. While the resultant wear from this action is not serious in most cases, there are occasions when the wear may be so great as to cause an increase in the steam consumption. It appears to be a well-established fact that steam of good quality, issuing at a low velocity from an orifice, does not appreciably erode turbine blades, yet it is equally true that, with the presence of moisture in steam moving at a high velocity, the erosion occurs at a greatly increased rate.

There appears to be an almost absolute lack of data of any kind relating to the erosive action of steam, aside from the results of very indefinite experiments conducted by Mr. Francis Hodgkinson in 1904, in which he only ascertained that the wear increased with increase in velocity of steam. To obtain some reliable data concerning this question, Mr. J. E. Wolf and the writer, in fulfillment of thesis requirements, conducted a series of tests upon two Kerr turbine blades.

Theory Concerned

The theory concerned in the tests is as follows: In calculations concerning the flow of steam, it is assumed that the flow is adiabatic, and then corrections are made, if necessary, from the results of actual tests. This assumption is made to include the conversion of all available heat energy into steam, without gain or loss of heat through conduction, radiation, friction, or otherwise, and the permanence of the amount of energy in the steam at all steps in the process, though the form of energy may be changed. Suppose that steam is flowing from the region of higher pressure (p_1) through a nozzle to a region of lower pressure (p_2). Under the assumption made above, the expan-

sion is a frictionless, adiabatic one, and the drop in the heat contents (H_1-H_2) is used to increase the kinetic energy of the steam jet. If (V_0) denotes the theoretical velocity of the steam issuing from the nozzle, then the kinetic energy of a pound of steam is $\left(\frac{v_0^2}{2g}\right)$ foot pounds. This increase in kinetic energy is equivalent to the heat given up during the expansion. Since one British Thermal Unit is equivalent to 778 foot-pounds, the work equivalent of the heat given up during any expansion is

$$W = 778\ (H_1 - H_2)$$

Substituting for (W) its equivalent $\frac{v_0^2}{2g}$

$$\frac{v_0^2}{2g} = 7.78\ (H_1 - H_2), \text{ or}$$

$$v_0 = 223.7\ \sqrt{H_1 - H_2} \qquad (1)$$

Frictionless flow of steam is never obtained in practice, because the friction of the nozzle can not be avoided. A relation can be determined, however, between the actual and theoretical velocities: Let (x) be the fraction of the heat drop ($H_1 - H_2$) which is lost in friction. Then, from formula, (1), letting (v_1) be the actual velocity.

$$\frac{v_1^2}{2g} = (1 - x)\ \frac{v_0^2}{2g} \text{ or}$$

$$v_1 = v_0\ \sqrt{1 - x} \qquad (2)$$

Practice has shown that the friction loss is approximately 10% of the heat drop ($H_1 - H_2$). Then $1 - x$, where $(x) = 0.10$, equals approximately 0.95, or the actual velocity is approximately .95 of the theoretical velocity.

Description of Apparatus

Two sets of apparatus were used at the same time in the performance of the tests, one in which steam of the best quality obtainable was used, and the other in which comparatively wet steam was obtained. Each set of apparatus consisted of a diaphragm, or plate of cast iron, inserted between two sections of six-inch pipe. One of these pipes was

connected to the steam main, the other to the condenser, gate valves being inserted in each connection. The center of the diaphragm was bored to permit the insertion of various nozzles designed for different steam velocities, a steam tight fit being made between the nozzle and the diaphragm. On the condenser side of the diaphragm was bolted an adjustable bracket for holding the turbine blade directly in front of the nozzle outlet. Gages were connected to the pipe on either side of the diaphragm, and a throttling calorimeter was connected on the live steam side.

Method of Performing Tests.

Steam was admitted at full pressure on the live steam side of the diaphragm, and allowed to flow through the nozzle, striking the turbine blade at approximately the same angle at which the entering steam strikes the blades in a turbine. Tests of ten hours duration were made, readings being taken at fifteen minute intervals of the steam in the calorimeter and of the pressures of the steam on either side of the diaphragm. At the end of each test, the blade was removed from the apparatus and carefully cleaned, dried, and weighed.

By means of the valve in the pipe on the exhaust side of the diaphragm, the steam pressure could be regulated so as to obtain any desired velocity through the nozzle. Constant pressures on the steam side were maintained as nearly as possible throughout each test. In order to study the effect of wet steam, the pipe on the live steam side of one set of apparatus was wrapped in waste, over which a continual stream of cold water was kept running. This caused sufficient condensation within the pipe to reduce the quality of the steam by approximately two per cent.

In the first set of apparatus, the steam as obtained from the steam mains was used; it had an everage quality of 99.5%. In the second set the quality of the steam was reduced to approximately 97.5%. Low steam velocities were used to begin with, the first determination being made with an exhaust pressure as near as possible to the critical (or 0.577 of the initial pressure). The velocity was then increased by increments of approximately 500 feet per sec-

ond, at least two tests being run at each velocity, until a velocity of approximately 3000 feet per second was obtained.

Discussion of Results.

The results of the experiments, as shown in Fig. 1, indicate quite definitely the action, upon the turbine blades, of steam of different qualities moving at various velocities. The most important result achieved was the collection of sufficient data to make a comparison of the relative erosive effects of dry and of wet steam, and of steam flowing at low and at high velocities.

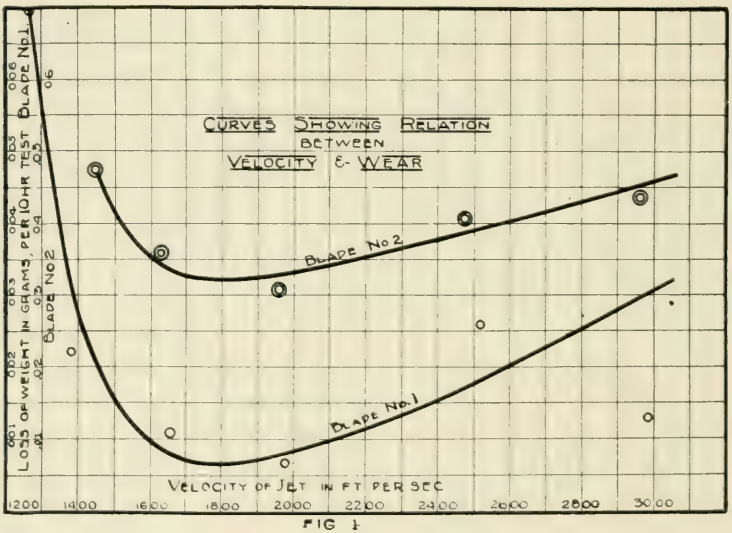


FIG 1

On blade number one, against which comparatively dry steam impinged, the total number of hours' test was 150, with a resultant total wear of 0.0416 grams. On blade number two, subjected to the flow of wet steam, but 100 hours of test were made, yet the wear was 0.5713 grams, or approximately nine times as much as in the first instance. The quality of the steam in the second case (97.5%) was but two percent lower than that in the first case, and even at that may be considered commercially dry steam. It will be noted that in the case of both blades there was a great amount of wear in the first one or two tests; this was probably due to

the polishing away of little projections on the surface of the blade which were not removed by machinery.

It must be borne in mind that in these tests the velocity of the steam was absolute, and that in a turbine the effective velocity is the velocity relative to the buckets. Since in the Kerr turbine (the type from which the blades used were obtained) the nozzles are converging and the absolute velocity of the steam is not over 1400 feet per second, the determination of the velocity of the steam relative to the blades brings the effective velocity down to about 1200 feet per second, a velocity so low that its effect upon the blades is almost inappreciable.

PERMISSIBLE EXPLOSIVES USED IN COAL MINES.

J. J. RUTLEDGE, Ph.D.
Mining Engineer and Geologist.

Owing to numerous disastrous explosions in the coal mines of the United States, which are believed in many cases to have been caused by the use of black blasting powder, the manufacture of permissible explosives has increased rapidly during the last two years. At the present time these explosives are used in many of the mines in Western Pennsylvania, and, to a limited extent, in the mines of Northern and Southern West Virginia, in Southern Illinois, Eastern Oklahoma, and in Alabama, and it is quite probable that their use will be very greatly extended during the coming year.

The various permissible explosives may be divided into three classes. First: those known as Ammonium Nitrate explosives; Second: the Nitro Glycerine explosives; Third: the Hydrated explosives.

Tamping.

Permissible explosives are usually tamped with moist clay. The clay is made up into dummy cartridges of about one foot in length and of slightly smaller diameter than the drill hole. A wood rod which is about one foot longer than the drill hole is used to tamp the explosive. In some coal fields, air spaces are left between the tamping in order to lessen the force of the explosive and adapt it to the particular coal being blasted. There is considerable variation in the degree to which the tamping is tamped, some permissible explosives requiring tight tamping, while others require loose tamping in order to yield best execution.

Firing.

In some coal fields permissible explosives are fired by fuse and detonator, but fuse firing is attended with many dangers, probably the most serious of which is the ignition of bodies of standing gas by the naked flame employed to light the fuse, or by the spitting of the fuse itself. The best practice is to explode the shots by electricity, as this is very much safer than using fuse.

In some cases the miners fire their own shots, in which event fuse is generally employed. However, such a plan does not yield as good results as firing by electricity. The cost of the electric detonators is about the same as that of blasting fuse of the same length, and, for this reason, if for no other, electric detonators should be employed.

The permissible explosive shots are often fired by special shot firers, who patrol the working places and fire the shots upon request of the miners. These shot firers carry a magneto electric machine in some cases, in others an electric shot firing lamp, and in still others, a one or two-cell dry battery with a safety contact button. They fire the shots in most instances while the miners are still in the mine. A careful inspection is made of each shot hole previous to loading and tamping it, and the shot-firer satisfies himself that the place is securely timbered up to working distance of the face before beginning his work. If the shot hole is not properly located, or the place is not well timbered, in the shot firer's estimation, the shot is not fired.

In some fields the entry or district bosses act as shot firers. One shot firer is usually sufficient for each 200-300 gross tons of output. Usually the company pays the shot firers, though not always. The cost is about one cent per gross ton of output, in cases where data was available, but it may in special cases amount to as much as two cents per gross ton. Firing shots by special shot firers is more systematic, more economical, and generally yields much better results than firing by miners.

Gas.

In high volatile coal beds, making considerable fine dust and generating considerable inflammable gas, the use of permissible explosives is absolutely necessary on account of the ignition of bodies of standing gas in the working places by the flame yielded by black powder. When properly prepared, the permissible explosives are practically flameless and there is freedom from gas or dust ignitions.

Ignitions of gas or firing of the coal face, after the firing of permissible explosives, are rare, but occasionally occur. In nearly every case, so far as observations extended, these ignitions resulted either from defective explosives or

from the near approach of a naked lamp to the coal face immediately after the firing of the shot.

Cost.

The price paid per pound for permissible explosives furnished the miner by the companies varies from 12 to 14 cents. As a rule there is no profit made on the explosive, the amount charged only covering the wholesale cost of the explosive with the expense of handling same added. Generally the miner pays one-half cent per foot for fuse and from one-half to three-quarters of a cent each for detonators. The electric detonators cost from 3 to 5 cents each, depending on their relative strength and length of wires. Usually when such are used the coal company furnishes them to the miner free of cost.

From data obtained from numerous coal companies in various parts of the country, who are using the permissible explosives, the cost of such explosives to the miner varies from one to one and three-quarter cents per gross ton of coal produced. This is exclusive of cost of shot firing, as these firers are in most cases paid by the companies. Their cost should not be more than two cents per gross ton of coal mined, and in most cases varies from one to one and one-half cents per gross ton.

Comparative Amount of Small Coal Produced by Black Powder and Permissibles.

Data as to the relative amounts of fine coal produced by black powder and permissible explosives is not easily obtained, owing to the relatively recent introduction of the latter, and the additional fact that they are mostly used in fields where the car system of paying for coal mined prevails, in which system the miner is paid a certain amount for each mine car loaded, and the coal is not weighed in the mine car, hence the amount of coal mined is not readily ascertained. Estimates by mine superintendents and data from screening tests vary from zero to ten per cent as the increased amount of fine coal due to the use of permissible explosives. Some mine superintendents state that while the lumps of coal yielded by permissible explosives are usually somewhat smaller than those from black powder, still the aggregate amount of coal passing over the same size screen

is no different in either case. This opinion is expressed by coal mine superintendents in widely separated coal fields.

The permissible explosives are much stronger and quicker than black powder, and must inevitably shatter the coal more than black powder when in the hands of men inexperienced in their use. However, a considerable amount of the difference should justly be charged to the inexperience of the person using the permissible explosives. In most cases, where care and judgment are used and the coal has been previously properly undercut, the permissible explosives make as good coal, at approximately the same cost, as black powder.

Failures.

Failures of permissible explosive shots may be due to four causes:

First. Frozen or deteriorated powder.

Second. Improper detonation; that is, the detonator used was too weak to detonate the charge.

Third. A displaced detonator.

Fourth. The wires on the electric detonator may have lost part of their insulation, or the same accident may have happened the leading wires extending from the electric detonator to the magnetic machine.

Advantages.

When permissible explosives are properly employed, ignitions of standing gas or broken coal are very rare. The roof, whether of coal, slate or shale, is not shattered as much as it is when black powder is used. In some coal fields the ribs are much better trimmed by permissible explosives than by black powder, and in one case there was an increase of 1½ tons per cut over black powder, owing to this trimming effect. On the other hand, when the drill hole is drilled on to the solid, the new explosives merely expend their energy at the end of the hole, forming a crater at that point, but not cutting ahead on the solid. If black powder is thus placed, windy shots often result, while with permissible explosives this rarely occurs. Moreover, the ribs cannot be stepped or robbed by drilling holes on to the solid as they can when black powder is employed. Coal blasted by permissible ex-

plosives is not scattered over the job, nor are the timbers displaced, as is often the case when using blackpowder. Generally, the position of shot firer is more easily filled when permissible explosives are employed in blasting. The miner requires less tools to prepare his shots for permissible exploives than for black powder. These explosives being much stronger than black powder, the same effective charge usually occupies about one-half the space that a black powder charge of the same strength would, hence there is much more tamping on the permissible explosive than on the black powder charge and a relative increase in safety. Since infinitely less smoke results from the use of permissible explosives than from black powder, the miner has a better opportunity to examine the roof and sides after blasting and there is a corresponding increase in safety.

Most prominent among the disadvantages connected with the use of permissible explosives are the following: Nearly all of them freeze at a rather high temperature and require careful thawing before they can be safely used. There is some variation in the diameters of the cartridges of various manufacturers and this fact causes trouble when one brand is susbstituted for another. When black powder is fired, but two factors are concerned in the explosion, viz: the fuse or squib, and the powder, while with the permissible explosives there are three factors concerned in the explosion, viz: the explosive proper, the electric detonator, and the magneto machine. The failure of any one of these three to act properly will result in a failure of the blast.

ENGINEERING SHOP PRACTICE; ITS RELATION TO MANUAL TRAINING.

FRED DUANE CRAWSHAW, M. E.
Assistant Dean, College of Engineering.

Manual training is a term applied to hand work taught in schools which are designed to give instruction to students in the underlying principles of industrial and shop processes. It is considered a subject of cultural as well as of technical value because it is supposed to deal with the fundamentals of education while it is training him in certain technical processes and giving him a certain skill in the handling of tools.

The mere fact that manual training is generally conceded to have a two-fold object, viz.: educational in the broad sense of this term, and instructional in the technical sense—has led to a great diversity of opinion concerning the nature of manual training courses. Some educators contend that all manual training from the kindergarten through the high school must be based upon psychological and pedagogical principles. This has been the means of forming different schools or classes of manual training teachers, such as the social-industrial school, the ethical culture school and others; each having certain laws which have been established by the psychologists and students of education. Another class of manual training teachers, generally those whose early training was in the engineering schools or in the industries holds that manual training, especially in the high school, must be preparatory to engineering and industrial activities. Consequently, it must deal jointly with technical and industrial processes and therefore develop skill.

While it is true that manual training first got its basic principles from such great educators as Froebel and Pesstalozi, who studied the education of very young children, it is also true that in this country manual training was developed by men who were primarily interested in manufacture and the education of mechanical specialists. In consequence of this last fact, in the United States it was started in the upper high school grades with boys and girls just entering

into manhood and womanhood. From this point it worked down through the grades to the kindergarten.

Manual training started in the United States in such educational centers as the old Mechanic Arts High School in St. Louis, the Manual Training High School in Chicago, and the Mechanical Department of Purdue University. It was given a great impetus in these centers because it was advocated that boys and girls—and in the early years boys were considered principally—should be taught to use their hands so that when they left the high school, they would be prepared for a life of industrial activity as mechanics and as foremen and superintendents in manufacturing plants. A definite bread and butter value, therefore, was given to the work of these schools, with the result that elaborate equipments were installed for training in several branches of mechanical work. The wood shop, forge shop, foundry and machine shop very early became the places for manual training work.

Now this shop organization in the manual training school soon became the beginning of one of two things. First: A training—more or less inadequate to be sure—for the trades; or Second: A training in the direction of engineering education. This latter development came when, as students pursued their work in the manual training shops and as engineering work in this country assumed the dignity of a profession, there dawned upon the school authorities the possibilities of manual training as a preliminary step toward engineering.

Today, then, we have three distinct types of manual training schools in America:—

a. The manual training school which bases its course upon educational theory as developed in schools of education in such departments as those of psychology and child study. These schools produce teachers and philosophers rather than mechanics and engineers.

b. The manual training school which is located in a commercial and industrial center and is governed by a body made up largely of men from the industrial world. Schools of this type have for many years turned out men, a large percentage of whom have gone into manufacturing establish-

ments, but who have been found rather poorly prepared either as mechanics or men who become efficient foreman and superintendents.

c. The manual training school which has the same relation to the engineering college as the academy has to the college of liberal arts. These schools have given to their graduates a desire to do some day a high grade of investigational or experimental work in applied science, and so they have found a place in colleges of science and colleges of engineering.

In manual training shop courses in schools under heading *a*, one finds work being done which has a distinct theoretical basis. The course of study is based upon an outline which in many cases has been furnished by the school's Department of Education. Particular attention, therefore, is paid to the working out of educational theory in the development of motor activities. The subject of interest is often given first consideration, and in not a few cases a misconception of this much abused word is the result. Pupils are allowed to start large projects without much, if any, preparation in tool manipulation. Furthermore, the object of this kind of work is neither technical skill nor the completion of objects which have a distinct utilitarian, industrial or shop value. Rather, the object seems to be gratification of childish whims. In such courses students are liable to find that they have overestimated their ability. Before their undertaking has assumed any definite proportions they are discouraged and the project is abandoned. The value of constancy of purpose, which always results in the building of character when a problem is continued to its completion, is lost as is also the prime motive of such a course, viz: the working out of the child's own ideas. In fact nothing seems to have been gained in such a process. It is a question if the student has not actually lost, because his lack of success has developed in him just the reverse of those sterling qualities which count for success in men's achievements.

The shops in such schools are not infested with the spirit of investigation, neither are they commercial in the sense that the spirit of industrialism pervades them. They are neither laboratories nor shops in the best sense. It is pos-

sible that the training received in them leads toward pedagogical research, but it certainly does not lead toward commercial or engineering activities.

Shop courses in manual training schools of type *b* are the ones having most prominence at the present day, principally because they are the oldest. They started as a result of a feeling on the part of some educators and many business men that the ordinary high school courses does not give a boy a training which will enable him to make a living. Courses in these schools are not designed nor are they constructed to teach trades; they are planned to teach the fundamentals of trades and to develop more of the human faculties than the courses in the ordinary literary or classical high school develop. As a rule they have accomplished their purpose. They do not, however, unless the school has truly become a trade school, make bread winners. The result of this deficiency has led to the present wave of industrialism in education, which is forming public opinion in favor of the trade and industrial school.

Shop courses in these schools are based upon established educational theory and upon fundamental trade principles. They have won, therefore, the commendation of educators and manufacturers. The mechanical processes that are taught generally develop in the student clear thinking and a fair degree of technical skill. They usually open the eyes of the student to this extent: he is able on the completion of his high school course to determine whether or not he is adapted for mechanical pursuits. As a result of this decision, most graduates from these courses make few serious mistakes in choosing their careers. They at least serve as a coarse screen to separate boys of mechanical bent from all others. As a rule these boys, who find themselves in the preparatory class for engineering, either pursue their studies in an engineering college or at once enter upon some mechanical or industrial pursuit.

While it is true that some of the students from type *b* schools enter engineering colleges, it is quite as true that they do so in spite of these schools rather than because they got preparation for the engineering colleges in these schools. Since the engineering college has come into prominence, the manual training schools have naturally considered them-

selves feeders for the engineering college. As a result, some of the manual training school shop courses, as well as other courses in these schools, have been changed to prepare boys definitely for engineering work. It is not uncommon for a boy to say on entering a manual training school, "I wish to prepare for ——— ———" (giving the name of an engineering college). If the school has met the demand of such students, it has modified its shop courses, so that for this particular class of students an engineering tone is given to their shop work. Some schools have even gone so far as to separate into different shop classes those who propose entering engineering colleges and those who intend to leave school with the completion of their high school work.

Now the secondary school shop course, which prepares for engineering college shop work, differs principally from the shop course given other students in these particulars:—

1*st* Students are constantly led to see that their shop work means to them advanced credit in the engineering college. This means that the high school attempts to duplicate the shop work of the engineering course.

2*nd* The shop courses are planned to correlate with the science departments, so that a knowledge of physical and chemical laws is exemplified in the shop work.

3*rd* Mathematics is applied in the shop work and given a turn which leads the student to think of the mathematics-shop combination in future engineering study.

4*th* Laboratory experiments are performed in the shop and are given in connection with shop problems as characteristic parts of shop courses. Speed tests and calculations, power measurement and efficiency tests, simple tests in stength of materials—such as bending and breaking under different conditions—, and numerous other ordinary laboratory operations are used to embellish and vitalize the shop work.

Now it must be evident because of the variety of purpose in these high school shop courses, and the self sufficiency of or lack of real purpose in the engineering college shop courses, that the shop preparation which the engineer of today gets is either a series of duplications or else a combination of theory and practice, which may or may not meet

his needs. With this analysis of the present situation, it is my purpose to outline in some detail certain phases of shop courses which, through the high school, but more particularly in the engineering college, will be engineering as well as mechanical in character. Before doing this, however, I suggest the following kinds of shop work through the high school and college, which seem to me essential for the student who is being educated in the direction of engineering. In doing this I am not supposing that other lines of work might not well be offered. Such other work, however, is not considered of first importance for the student in question.

1*st* Woodwork in the following order:—Bench work, turning, pattern making and framing.

2*nd* Metal work in the following order:—Bench work including chipping and filing and sheet metal work, speed lathe hand tool turning and spinning, forging and machine construction with laboratory practice as a necessary adjunct.

3*rd* Foundry work in the following order:—Snap flask molding, loam molding, metal mixing and testing.

It is assumed that in connection with the above lines of work an intimate correlation will be developed between the shops and the science and testing laboratories; otherwise a fourth line of work would be indicated, which would outline the experimental and investigational side of the shop courses. It is also assumed that problems of economy of labor and production will be made prominent in the above outlines.

Below appear some of the essentials in each of the above suggested courses.

1st WOODWORK

As manual training is now organized, bench work in wood is very often begun in the upper two grades of the grammar school and continues through the first and sometimes through the first two years of the high school. If this is the case, the course should be so planned for these years that there will be little if any duplication of effort when the student leaves the grammar school and enters the high school. The continuity of the work, as well as its character, should make a lack of interest on the part of the student impossible. Stress should be laid upon the place wood should have

in machanical and enginering work by introducing problems which have a direct bearing upon practical out-of-school problems, and by giving illustrated talks which will forcibly demonstrate the use of wood in general construction work. It is quite essential in these early years that the student should be impressed with the fact that an accurate determination of sizes in construction is quite as necessary as accurate construction itself. To this end the course should provide for testing wood and different kinds of wood used under different conditions. Without the mathematical knowledge necessary to calculate for safety in construction, simple devices may be planned to show by experimental means the comparative strength of different woods and different sized pieces of the same kind of wood. Such work will early lay the foundation for independent thought and investigation on the part of the student.

At the end of the first two years in the high school, the average student should know how to handle and be able to do good work with the ordinary woodworking tools and machinery. In addition to this, he should have developed a judgment upon wood construction, which will enable him to select the best woods and use the most effective joints for ordinary wood construction that does not involve the use of elementary mechanics. I would exclude from the course up to this point problems in roof and bridge construction, which are sometimes given in high school courses for the first two years.

A course in wood turning and pattern making follows the course in bench and machine work in wood. Inasmuch as pattern making involves the use of wood turning tools, I deem it wise to carry on courses in wood turning and pattern making simultaneously. Time is gained by this arrangement and besides, the student applies his wood turning in a work which has a trade significance and therefore, at least, an engineering bearing.

The usual method of teaching wood turning is to demonstrate and explain how each of a number of articles are turned. To my mind, the result of this is mentally, as well as physically, a mechanical process. If so, the student becomes by this method an operator through continued practice. He does not, however, necessarity become a thinking

operator. I am sure that in all wood turning a mathematical analysis is possible, and that the method of teaching it is not by showing the student *how* to turn a particular form, but *why* the tool is used in a particular way to accomplish certain results. The mathematical principle of tangency is the basis of all wood turning cuts; and when the student has a knowledge of this fact and appreciates its application in the use of each woodturning tool, he has mastered the art of woodturning. He may then acquire skill in wood turning in a course in pattern making, rather than by turning exercises which have no meaning for him except as practice work.

For the student who is looking toward engineering as his life work, the why of any problem is quite as essential as the how, and for this reason, if for no other, the method of approach above indicated is a desirable one to develop a correct mental attitude.

The first work in pattern making, and the only work in this branch of wood construction which should be taught in the high school, must deal with the principles underlying the pattern maker's trade. There is so much involved in pattern making which requires a knowledge of other trades, that the high school student has quite enough to do to master and appy the principles of shrinkage, draft, finish, etc., together with gaining a correct knowledge of ordinary pattern construction. I would reserve for the college course in pattern making all work in machine pattern making, including problems in design, testing and economic production.

The student's shop work in wood in his engineering college course is limited to a course in pattern making, suggested in the last sentence of the above paragraph, and to a course in framing. If the student's high school course in pattern making has been of the character above described, his college course in this subject need lay very little stress upon which has been called, "the principles underlying the pattern maker's trade". He may at once begin the construction of patterns for machine parts. In doing so he should be brought face to face with the problems of design and economic production. In the design of a pattern he must consider the use to which the casting is to be put, which immediately raises the question of strength. This involves calculations and tests under working conditions. He studies the

subject of mixing metals and compares the iron casting with the steel casting. He inquires into the present methods of ascertaining why patterns are so carefully designed and redesigned for the castings of model machines, and seeks to improve upon these methods. In short, he is not a pattern maker alone, but an engineer who is looking for the best possible production as the result of experiments, investigations and such calculations as he may use.

In the construction of the pattern he must be guided by the thought that his patterns are to be used under different conditions of production. Is there to be one casting or many castings to be made from a pattern? Will it pay to make a very substantial pattern or should he use a skeleton form? Or, perhaps, will a loam pattern, when time, expense and finished product are severally and collectively considered, be best? The construction of the pattern should really be a small part of the college student's work in the pattern making course. From the larger consideration of his work he must get that broad view which can only be obtained by his placing himself as nearly as possible in the position of the manufacturer or engineer whose success depends upon his bringing to bear upon his problem all the fruits of his own and others knowledge.

From personal experience as a teacher of a college course in framing, I have become convinced that such a course serves as a climax for school wood working in engineering courses. The student in his college sophomore year has had descriptive geometry, some mechanics and enough mathematics to solve many of the problems in roof and bridge construction. In the design and calculation incident to the construction of roof and bridge trusses, there is found the meat of engineering work. Nothing, so far as I know, so well serves the purpose of demonstrating the value of the college shop as a part in engineering training, as does a practical course in wood framing.

2nd METAL WORK

Metal work of any consequence seldom begins before the second or third year in the high school. If begun at this point, the work is usually in thin metal and is art metal work in some form or other. The metal work which may be considered of direct value to the student of engineering tenden-

cies, begins as a rule in the last high school year or the first or second year of college. Little can be said concerning the early bench work in metal, which will affect present beginning courses already established in elements of engineering principles. It is well that every engineering student should be familiar with as many shop processes as possible. A precise and definite work in chipping, filing, sheet metal pattern construction and hand tool turning, which has a definite relation to similar work in commercial shops, cannot help but be beneficial. Care must be taken not to consume too much time in his work, however, as it must be clearly understood that such work is given engineering students largely for the purpose of familiarizing them with shop processes. It is not given for the purpose of making skilful workmen.

Forging in engineering courses might be put in the same class as the metal work just mentioned so far as its purpose is concerned. If I should criticize the average college course in forging, I would condemn the practice of consuming time in making many things simply for the things themselves, regardless of the kind of work involved in the making. Some schools run to art forging, others to tool making, and so on, but few emphasize in a comparatively strong way the use of different kinds of iron and steel and the best methods of handling them in the fire. Much of real value for future engineering work might be introduced in the forge shop by making comparative tests of heated metals under fixed conditions. I suggest also the introduction of drop forge work and working with large pieces of metal under power hammers. The engineer is much more liable to be called upon to deal with heavy metal construction than he is with light metal construction; hence, the necessity of a knowledge concerning the manufacture and use of heavy metal construction parts.

It is in the machine shop, however, where I would suggest the greatest changes in school shop practice. So far as I am able to learn, there are comparatively few of our engineering colleges that lay much stress in the machine shop upon manufacturing as such, or upon shop methods which may be termed engineering in character. Machine shop courses as they are at present outlined, emphasize machine manipulation. The average student, when he has completed

his machine shop course, has very little knowledge of how a machine shop should be organized and operated to produce economic results. He has almost no idea of shop efficiency. He has been technologically taught but the questions of labor and cost have been ignored in his education. According to the report of the last President of the American Society of Mechanical Engineers, fifty per cent of the members of the Society are directly connected with the organization and management of capital and labor. It would seem that our machine shop courses should be designed to apply to business methods by correlating properly conditions of commercial economy with conditions of pure techique, if engineering students are to get a proper training for the work which this report indicates they will do. Much of the present work of "muscular effort" and "finger skill" should be substituted by work involving "critical comparison".

The machine shop course then, which I propose, will minimize hand work as such and introduce more class work and demonstrating work which deals with practical engineering problems. Machines will be run to produce economical results as well as technical results. They will be run under different power conditions and under different loads produced by different tool cuts and speeds. Efficiency tests will be made. Estimates of wear and tear in machines will be made. Judgment will be formed upon operative and maintenance cost. Shop designs and arrangements will be studied. The relation of the power plant to the machine shop will be determined both as regards location and operation. In a word, the student will be trained to observe, criticize and pass judgment upon economic shop management and production, rather than to operate machines as an individual mechanic. By so doing and because he will receive instruction which will contribute toward the practice of his future profession, rather than that of an industrial workman, he will acquire the mental attitude of the engineer.

3rd FOUNDRY WORK

The course in foundry work should be planned upon the same broad lines as those suggested for the course in machine shop practice. The engineering student is not getting his just deserts, if from his work in the foundry he gets only a knowledge of ordinary job shop work. This he should get,

to be sure, but comparatively speaking this will be of little value to him in his engineering growth or in future engineering practice. With and in addition to this, he must be given the opportunity to "engineer" some problems in foundry practice. Let his course provide instruction in metal mixing and testing, in sweep work and loam molding, in cost computations and in methods of producing castings for "hurry" jobs. Give him the management of the foundry for a day and force him to get results under definite requirements. The foundry affords an opportunity for such an experience with comparatively little danger of serious results.

I feel certain that in the somewhat detailed presentation of the framework of a course of study in wood work and in metal work, I have made my point clear. It is my belief that it is only just to the engineering profession that the schools which send men out into the field of engineering should embellish their shop courses by adding practical accompaniments to the commonplace shop technique. In accordance with an old saying, "Where there is smoke there must be some fire", when we find many of the practical engineers of today complaining of the college preparation of engineering students, we may safely conclude that something can be done to make this preparation better. I have endeavored to show how the shops may help to do this.

In conclusion I would summarize as follows:—

1. So organize the shop work of the secondary schools and colleges that a definite and continuous line of shop work throughout both may be established.

2. Let the character of the shop work be such that the student will live and grow in an engineering as well as in a mechanical atmosphere.

3. Make every problem a possible one, to be dealt with by the student as he will deal with it after he leaves school: when he will be in practical competition with his fellows.

4. Minimize hand skill but give every student enough hand work in every shop process essential to engineering practice, to familiarize him with the best shop methods.

5. Enrich every shop course with lectures, demonstrations, investigations, experiments and tests which will give the student a wide angle view of the shop and its possibilities as a part of an engineer's equipment.

EFFECT OF KEYWAYS ON THE STRENGTH OF SHAFTING.*

JAMES C. LUND, B. S. IN M. E., '09.
Instructor in Metal Working.

It is of some importance to a designer, to know the effect of keyways on the strength of shafts, so he may allow for the loss of strength thus incurred, in the proportioning of shafts met with in machine construction. Therefore, during the past year there was carried on at the University of Illinois a series of tests on shafts subjected to combined torsion and bending stresses.

In these tests performed, a standard keyway was assumed. This was done, because different manufacturers use different standards and it was thought best to assume a keyway, which approximately represented the average of several so-called standards. This assumed standard keyway was based on the general formula: $^1/_4$d in breadth, by $^1/_8$d in depth, in which "d" represents the diameter of shaft. This would provide for a key of square cross-section, the dimension of which, would be one fourth of the diameter of the shaft.

The sizes of the Woodruff keyways were arrived at by computing the twisting force at the surface of the shaft for the maximum loads, and selecting Woodruff keys which were strong enough in shear to resist this force.

Shafts $1^{15}/_{16}$ inches and $1^1/_4$ inches in diameter with the following kinds of keyways were tested in duplicate; standard, extra wide, extra deep, and keyways to take Woodruff keys. All these shafts were subjected to combined twisting and bending, which represents the method of loading generally met with in actual shafting. For example, a pulley, located between bearings on a counter shaft, driving a machine below may serve as a good illustration of combined twisting and bending.

*The subject matter of this article was taken from the thesis submitted by Mr. Ollison Craig and the writer on June 1st, 1909, for the degree of Bachelor of Science in Mechanical Engineering.

The different variations of tests were as follows:

1. Shafts having a diameter of $1\ ^{15}/_{16}$ inches, keyways in horizontal plane, ratio of twisting to bending 10 to 6.

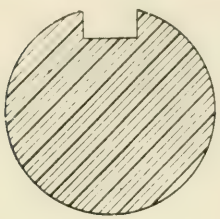


Fig. 1.

Diam. of Shaft $1\frac{15}{16}$ inches.

Standard Keyway, $\frac{1}{2}$ in. x $\frac{1}{4}$ in.

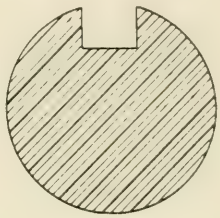


Fig. 2.

Diam. of Shaft $1\ \frac{15}{16}$ inches.

Extra Deep Keyway, $\frac{1}{2}$ in. x $\frac{3}{8}$ in.

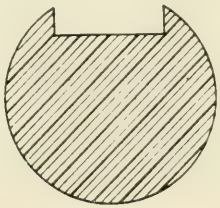


Fig. 3.

Size of Shaft $1\ \frac{15}{16}$ inches

Extra Wide Keyway,

1 in. x $\frac{1}{4}$ in.

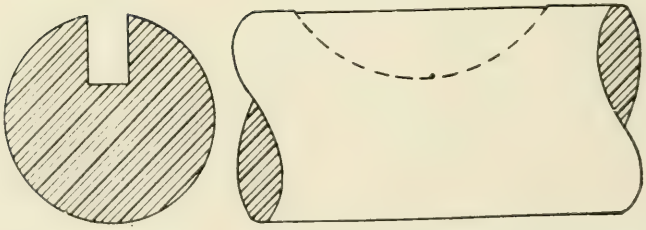


Fig. 4.

Diam. of Shaft, $1\frac{15}{16}$ inches.

Woodruff Keyway No. 3, 5/16 in. x 5/8 in.

2. Shafts having a diameter of $1\ ^{15}/_{16}$ inches, keyways in horizontal plane, ratio of twisting to bending 6 to 6.

3. Shafts having a diameter of $1\ ^{15}/_{16}$ inches, keyways in vertical plane, ratio of twisting to bending 10 to 6.

4. Shafts having a diameter of $1\,^{15}/_{16}$ inches, keyways in vertical plane, ratio of twisting to bending 6 to 6.

5. Shafts having a diameter of $1\frac{1}{4}$ inches, keyways in vertical plane, ratio of twisting to bending 10 to 6.

6. Shafts having a diameter of $1\,^{1}/_{4}$ inches, keyways in vertical plane, ratio of twisting to bending 6 to 6.

All variations of keyways were used in each of the six series.

All tests were run in duplicate.

Description of Apparatus.

To the ends of the test shaft s, Figures 5 and 6, are keyed rocker arms "a a" extending at right angles to the

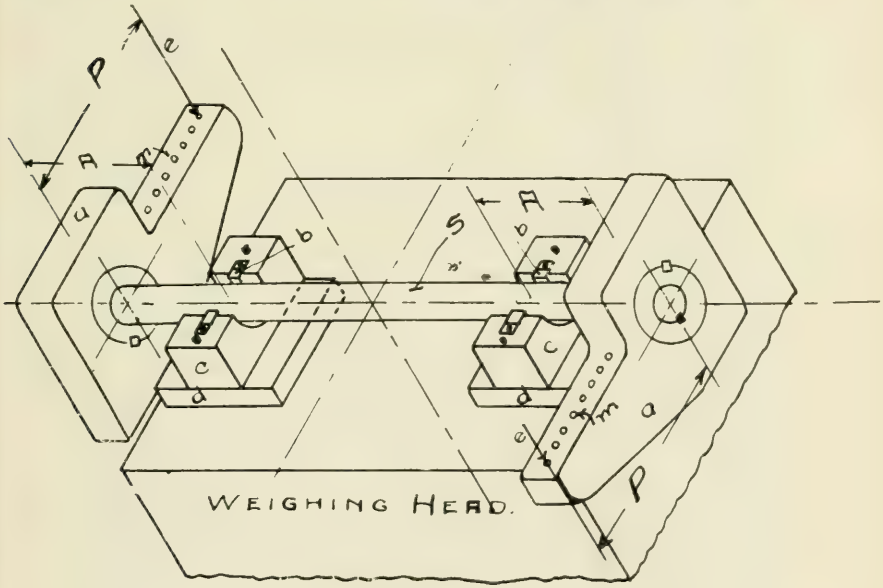


FIG. 5
DIAGRAMATIC SKETCH OF TESTING APPARATUS
COMBINED TORSION AND BENDING

shaft. Equal forces "e e" are applied in a vertical direction at points on those arms at a distance P from the axis of the shaft. The test shaft is rested in bearings "b" which are supported by steel ball bearings in a race in the block "c." The distance "A" from the arm "a" to the center of the nearer

bearing is the same at the two ends. The test shaft is thus subjected to the bending moment 'e A' over that portion between bearings, and to a twisting moment 'e P' over its entire length. The ratio of the twisting moment to the bending moment equals $\frac{P}{A}$

The forces "e e" were applied by the moving crosshead of the testing machine, the entire apparatus shown in Figures 5 and 6, resting on the upper weighing head of the Philadelphia, 100,000 pound capacity machine, in the Laboratory of Applied Mechanics at the University of Illinois. The load as registered on the weighing beam of the machine equals 2 e, the force "e" being transmited to each of the arms "a a" thru the tension rods. These arms "a a" have spherical recesses "m" which give different arm lengths into which the spherical pointed knobs on the tension rods fit. The bearing blocks "c c" can be moved axially along the shaft, over plates "d d," thus allowing the bending moment to be varied.

In measuring the twist deflection indicators "h h h" were arranged as shown in Fig. 6. These were especially designed for this purpose and answered very well. They consisted of three long arms clamped on to the shaft. One arm was clamped at the center, and the other two at equal distances with reference to the part of the shaft including the keyway and the solid part respectively. At the extreme end of the last two mentioned were placed scales glued onto mirrors. The center arm held pointers, under which these scales passed as the shafts twisted. Readings were taken from the scale in fiftieths of an inch. The approximate length of the indicator arm "h" necessary, was computed from the degree twist, that was expected; and the distance between arms, which was 5.5 inches.

When the testing of the $1\,^1/_4$ inch shaft was begun, it was noticed that the machine was too inaccurate for close work, the balance beam being too sluggish for the applied load. A needle beam was attached to the machine, immediately above the regular beam. This proved to be very satisfactory and the sensitiveness of the machine was such that the load on the specimen could be determined to within a ten pound load.

Procedure of Tests.

At first, some of the shafts were tested with the keyway in a horizontal plane, but owing to the fact that the neutral axis was in the same plane, the keyway was not subjected to

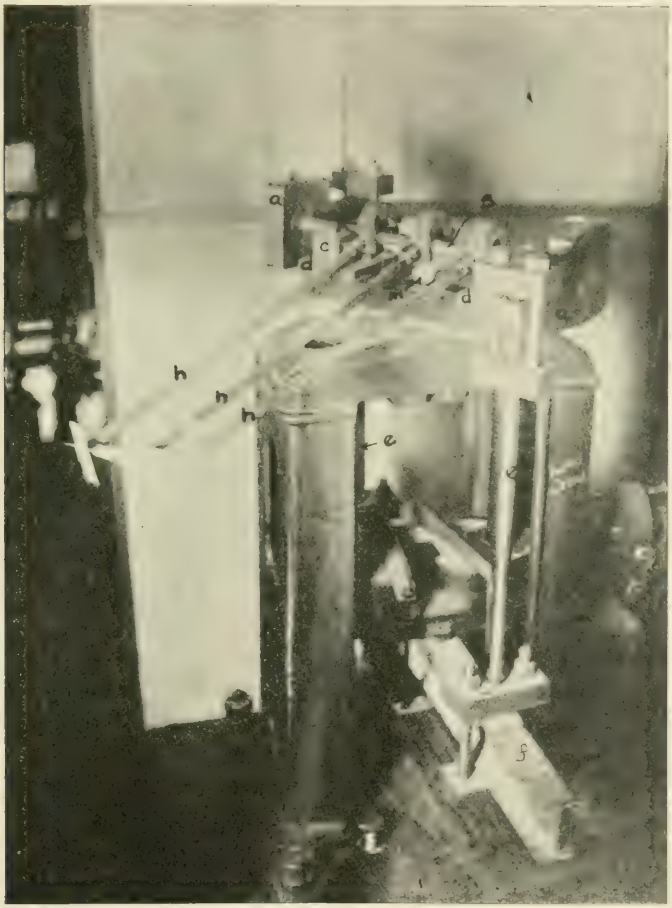


FIG. 6
APPARATUS FOR TESTING SHAFTS IN COMBINED TORSION AND BENDING

the maximum bending stress so that all later tests were made with the keyways in the vertical plane.

The load was applied in increments of 1000 pounds, for the $1\,^{15}/_{16}$ inch shafts and of 300 pounds for the $1\,^{1}/_{4}$ inch

shafts. A small initial load was applied to the shaft and an initial reading taken on the twist measuring apparatus; more load was then applied and the angle of twist read; the load was then released to its initial value, and the angle of twist again read, any permanent set being thus detected; a load slightly greater than the previously applied load was then put on the shaft, and this load in turn released to the initial value. This process was repeated with applications of increasing loads till the yield point of the shaft was passed.

Preliminary calculations were reduced to constants. Thus, in making calculations for the degrees twist, knowing the length of indicator arm, the distance the indicator arms were apart on the shaft, and the length of the spaces in inches on the scale, a constant was found, which, when multiplied by the scale reading, gave the degrees twist per inch of shaft. Similarly a constant was found, knowing the length of the twisting arm and the size of the shaft, which, when multiplied by the load, gave the unit stress in the metal.

Formulae and Sample Calculations.

(a) $M = \frac{P\,T}{2} = \frac{S\,J}{c}$ in which

M = Twisting moment in pound inches.
P = Load on scales.
T = Length of twisting area in inches.
S = Unit stress in metal.
J = Polar moment of inertia of shaft.
c = Distance from neutral axis to extreme fiber or, in this case, the radius of shaft.

Substituting in the preceding formula for the case of the shaft $1\ ^{15}/_{16}$ inches in diameter, ratio of bending to twisting 6 to 10.

$T = 10$
$J = 1.384$
$c = .9688$

$$\therefore\ P \times \frac{10}{2} = S\,\frac{1.384}{.9688}$$

$$\therefore\ S = 3.5\ P$$

(b) Derivation of constant for degrees twist per inch.

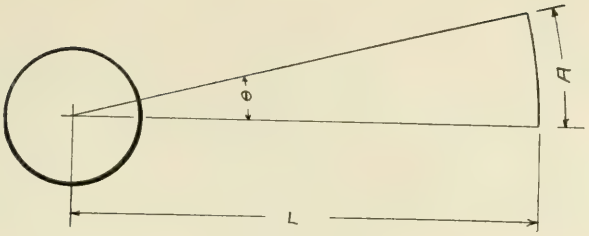


FIG. 7

$\theta = \frac{.02A}{L}$, in which

θ = Angle of twist in radious.

A = Scale readings in space.

L = Distance from center of shaft to scale.

Substituting for the case of the shaft $1^{15}/_{16}$ inches gives

L = 37.375 inches

$$\theta = \frac{.02\ A}{37.375 \times 5.5}\ , \text{ in radians.}$$

5.5 indicates the distance apart in inches the indicators were set on the shafts.

50 divisions on scale = 1 inch.

$\therefore \theta =$ in degrees per inch

of length of shaft $= \frac{.02\ A \times 57.3}{37.375 \times 5.5}$

$= .005575\ A$

Table Number 1.

General Average of Loss of Strength (in per cent.)	
Standard Keyway	14.15
Extra Wide Keyway (Double Width)	29.
Extra deep Keyway ($^3/_2$ standard depth)	26.
Woodruff Keyway	14.8

Table Number 2.

Loss of Strength in percent.
Standard Keyways.
Combined stresses.

Size of Shaft in Inches.	Ratio of 6–10	6–6
$1\frac{15}{16}$	25.1	15.6
$1\frac{1}{4}$	12.5	11.4

SAMPLE DATA

SHAFT No. 6

Load lb.	A	B	C	Unit Stress lb. per sq. in.	Twist A	Degrees per inch B
500	30	13	0	1750	0	0
1000	32	14	1	3500	.01112	.0055
500	30	13	0	1750	0	0
2000	37	18	3.5	7000	.039	.0279
500	30	13	0	1750	0	0
3000	40	21	6	10500	.0557	.0446
500	30	13	0	1750	0	0
4000	45	24	8.5	14000	.0835	.0613
500	30	13	0	1750	0	0
5000	49	27	11	17500	.106	.0725
500	30	13	0	1750	0	0
6000	52	30	14	21000	.1225	.0948
500	30	13	0	1750	0	0
7000	58	33	17	24500	.156	.1112
500	31	13	–1	1750	.0055	0
8000	72	36	22	28000	.234	.128
500	40	13	1	1750	.0505	0
9000	160	40	50	31500	.725	.1505
500	124	13	25	1750	.524	0
10000		45		35000		.1782
500		16		1750		.0167

Duplicate	Extra Wide
Length	30 inches
Diameter	$1\,{}^{15}/_{16}$ inches.
Size of Keyway	1 in. $\times$ $^{1}/_{4}$ in.
Twisting Arm	10 inches
Bending Arm	6 inches, Ratio $\frac{B}{T} = \frac{3}{5}$

A.— Left hand scale — (Keyway)

B. — Right hand scale — (Solid shaft)

C. — Deflectometer — (Center of shaft)

Keyway set in Horizontal Plane.

Conclusions.

1. The first set, in almost every case, took place under the load corresponding to the yield point.

2. The shafts weakened more by having the keyways in the vertical plane, than in the horizontal plane. When located in the vertical position the keyway was in the part of the shaft subjected to the greatest stress due to bending, while if put in the horizontal position it is practically in the neutral plane.

3. There was considerable loss in stiffness as is indicated in the following table.

Table Number 3.

Loss in Stiffness in percent.

Ratio of Twisting to Bending	Size of Shafts in Inches $1\frac{15}{16}$	$1\frac{1}{4}$
10—6	13.3	9.5
6—6	20.4	14.9

4. In general the keyways had a weakening effect in the following order:

Extra Wide	29 percent
Extra Deep	26 percent
Woodruff	14.8 percent
Standard	14.15 percent

The extra wide keyways had the greatest weakening effect, due to the fact that the most metal was removed from the part of the shaft that was subjected to the greatest torsional stress. Contrary to general opinion, the Woodruff keyways, next to the Standard keyways, showed the least weakening effect, because in cutting a Woodruff keyway, more metal is taken from nearer the axis of the shaft, and not so much from the outer fibers, which are under the greatest torsional stress.

5. It would be well, when selecting a shaft, to make allowance for the weakening effect of keyway. This could be done by assuming a working stress of 15 percent or 20 percent lower than that used in usual calculations.

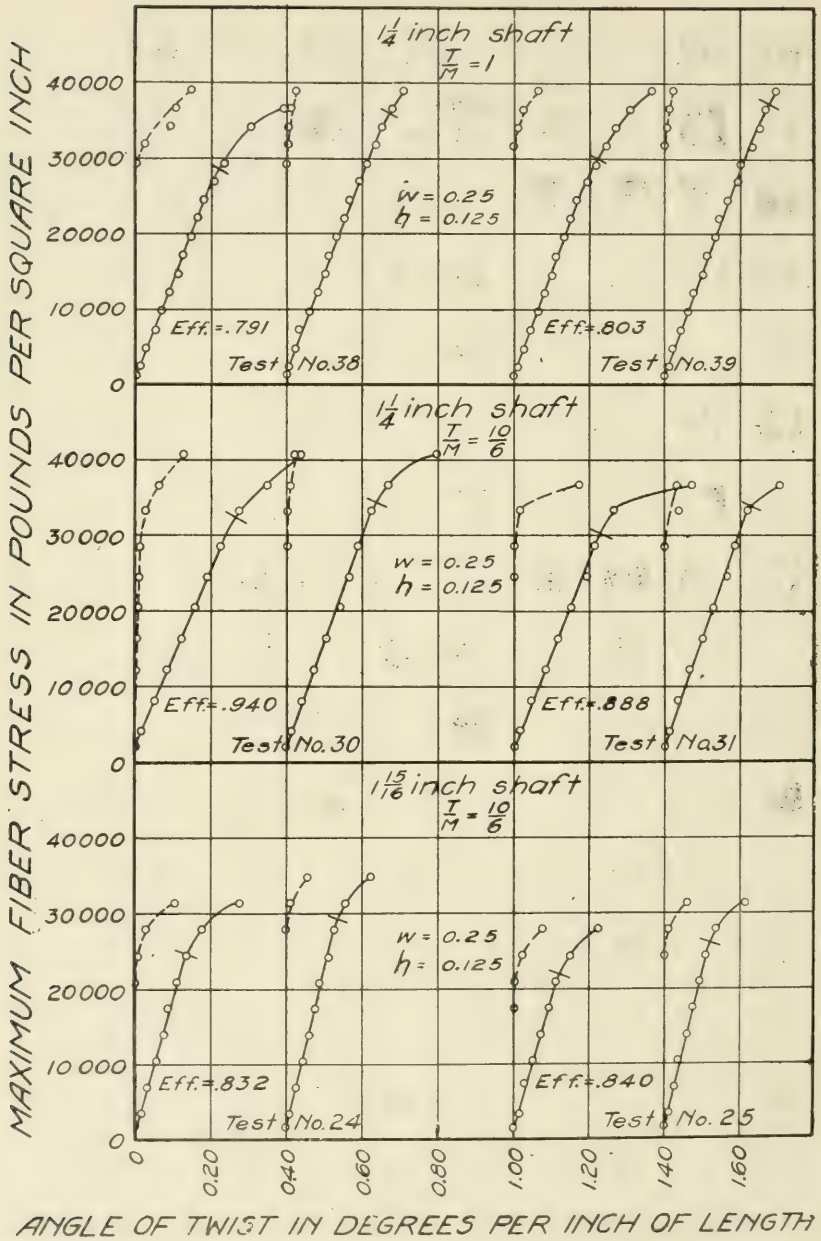


DIAGRAM OF TESTS UNDER COMBINED BENDING AND TWISTING

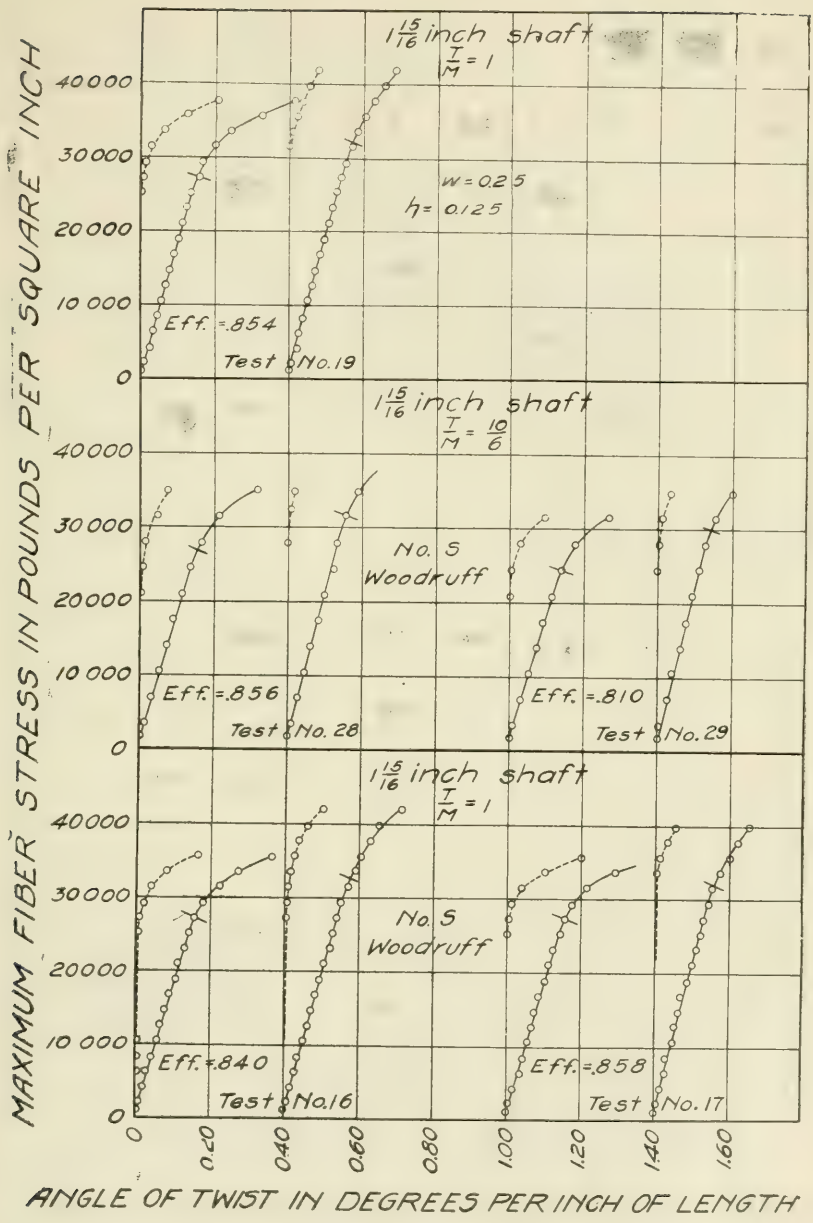


DIAGRAM OF TESTS UNDER COMBINED BENDING AND TWISTING

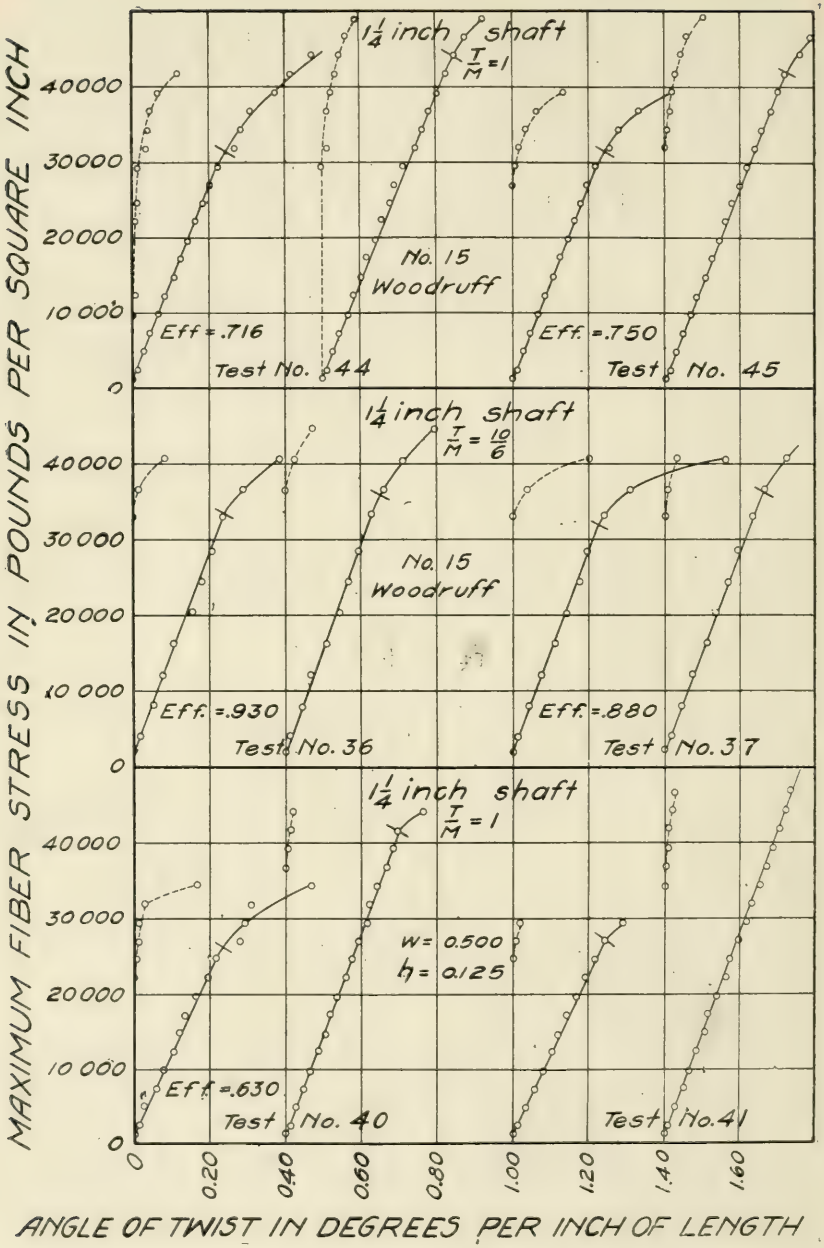


DIAGRAM OF TESTS UNDER COMBINED BENDING AND TWISTING

FILING MISCELLANEOUS ENGINEERING DATA IN LOOSE-LEAF NOTE BOOKS.

ARTHUR F. COMSTOCK, B. S., IN C. E., '06.
Associate Editor Engineering Record.

Every engineer, at one time or another, feels the need of a convenient system for filing miscellaneous data. The value of such a system, providing it has been given careful attention throughout his experience, is not apt to be over-estimated.

It was not many years ago that most filing was done in blank books. This method was cumbersome, because it was necessary to anticipate the amount of space which should be alloted to each particular subject, in order that all of the information on that subject should appear in its logical order. If such space were not provided, the result was that the notes pertaining to a certain subject were scattered through several books, making it necessary to have an elaborate index, which, at best, was slow and tedious to use. The blank book was superseded by the card index, which is now in very general use. A complete description of the card system for filing fragmentary engineering literature on a large scale, appeared in the Engineering Record of August 14, 1909.

The loose-leaf system, however, offers certain advantages over any other filing system yet devised, and is rapidly displacing the card system for many branches of filing. After three years' experience with both the card and the loose-leaf systems, and, at the same time, carefully observing the experiences of several of my associates, I am convinced that the loose-leaf system is the better one to start on. It is neat, portable, self-indexing, extremely flexible, and is susceptible of very ready reference.

One of the greatest faults of the card system is that it is not portable. Whether one is working in the drafting room, the library or elsewhere there is a considerable advantage in having one's data close at hand, which is clearly impracticable with the card system. The loose-leaf book, on the other hand, can readily be taken wherever it is needed. This feature, alone, is an incentive to keep the book always at one's elbow where it can be easily referred to, and where it is

most likely to receive the attention it requires to be kept up to date, both as to revisions and additions. Moreover, these revisions are more easily and more thoroughly made where all of the information relating to a particular subject is before one, as in the loose-leaf book.

Another valuable feature of the loose-leaf book is the quickness with which it may be used. Data once filed under a logical heading can be located almost instantly, because it is self-indexed. When opened, the book remains so without further handling. The whole page is clearly before one; and a page will usually contain as much information as a half-dozen or more cards. For example, if one were looking for the allowable compressive stress of 1:2:4 gravel concrete, and he turned to the heading "concrete" and the sub-heading "allowable Compressive Stress", he might find, in a well kept set of notes, references to or perhaps citations from several different authorities, and, in addition, some of his own observations.

The card system offers some contrasts to the advantages above stated. In the first place it is not self-indexed, that is, the index is usually separate from the matter indexed. This makes it necessary to look first in the index and then in the file, for any information desired. The differences in heights of cards often make them difficult to handle quickly, and their vertical position does not contribute to the ease of reading them. Further time is sometimes lost by having to pull the drawers out and take them nearer the light in order to read them.

The extent to which the loose-leaf system can be economically expanded, in book form, may be a matter of some doubt. Having only three books in use at present, I cannot say from experience that a dozen would be just as successful. It does seem reasonable, however, that where a loose-leaf system became so large as to require one or more books for each subject, the plan should work out satisfactorily.

If, however, it were found that too many books made the system unwieldy, (which would not be the general case) it could readily be converted into a card system. A better card system would result from this method than by proceeding without it, because the material would be already grouped and indexed and the cards would merely refer to the

subject matter on one or more loose leaves. An additional advantage would be that the leaves required for any given investigation could be taken out of the file and put into book form for temporary use.

There is scarcely any limit to the kinds of information that can be filed in loose-leaf books. Notes and comments on various methods and details of construction; principles of design; computations; price-lists; cost analyses; references to text books, technical journals, reports and proceedings of societies; small blueprints; business addresses; and many other matters can be readily included in the book. Large blueprints or other information in bulky form can be put away in drawers, or elsewhere, and indexed in the book. In short, one's ingenuity is the only limit to the development of the loose-leaf system.

The best type of book is that in which the leaves are held in place by rings opening in the middle. This device allows a leaf to be removed or inserted at any place in the book without having to remove the leaves on either side and thus saves considerable time. The rings should be not less than one inch in diameter, for, if smaller, they will not hold enough leaves. A standard make of book should be selected, so that the leaves and cover can be purchased in different localities.

As to size of book, I have found the 5x8-inch or the 6x9-inch to be the best for general purposes. A book of size 3 3/4 x 6 3/4-inch can be carried in the pocket, but is too small for many purposes. Where more than one book is used it is desirable to adhere to the same size, as it is then possible to interchange the leaves of various books. If many blueprints or catalog pages are to be filed, they should be placed in a separate book.

Square-ruled or cross-section paper is probably the most convenient for general use. Either one or both sides of the paper may be used, the latter scheme of course being more compact. In beginning a system ample space should be left between different divisions on the same sheet, so that additional information may be inserted in its proper place without re-copying the page. Cross-indexing should be employed freely. When it doubt whether certain information merits filing or not, the best plan is to file it until experience shows

its value. If there is any reason whatever to doubt the accuracy of any information filed, it should be clearly marked "questionable" until verified. Some system of capitalizing headings and underscoring the introductory words of paragraphs should be used in order that the scope of a reference may be determined at a glance. Clear, consistent and standard abbreviations should be used throughout; and some helpful suggestions along this line can be found in the Engineering Record of Jan. 29, 1910. Personal tastes will decide whether the notes are to be written, lettered or type-written.

CARBON STEEL.

JAMES HERBERT GILL, M.E.,
Assistant Professor of Machine Construction.

Carbon steel is now almost considered a "has been". Increased production due to the possibilities of the modern high speed steel has led to the extensive use of the new steel. Because of the remarkable properties of this steel, its use has increased until now no one pretends to do much with the old fashioned steel. In fact, the old carbon steel is out of fashion. That is one reason why carbon steel has been neglected. Another reason is that it requires much more skill to work and temper better grades of carbon steel than the high speed steel. Because of these reasons, the carbon steels have not had a chance to show what they can do.

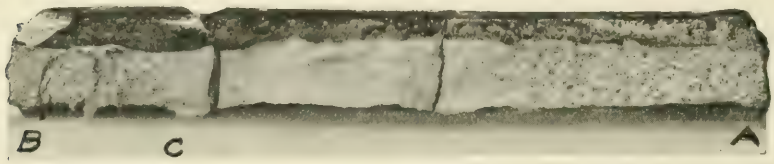
Carbon steel is a compound of iron with various amounts of carbon. The amount of carbon in the steel is measured in percent and varies from .60% to 1.75%. This is known as steel of sixty or one hundred and seventy-five point carbon. The grade or quality of steel depends on the freedom from impurities such as sulphur, phosphorus and others. Freedom from these impurities can only be secured by the use of the purest irons.

Steels of various grades differ in price. Each grade may be had with various amounts of carbon or various "tempers", using the word temper as the steel makers uses it, to mean the amount of carbon in the steel and not the degree of hardness. So price varies with the grade or quality of the steel, and not with the temper. The higher the carbon, the more sensitive the steel is to heat, or the lower the carbon, the more abuse by heat the steel will stand.

Carbon is commonly found in steel in two forms. Cementite, Fe_3C, is found in annealed steel. If the steel is hardened thoroughly the carbon takes a new form called Martensite, $Fe_{24}C$. The change from one form to the other takes place under the influence of heat. This change from Fe_3C to $Fe_{24}C$ takes place at about 1350 F. The exact point varies some what with the amount of carbon present. The lower the carbon content the higher the heat necessary. As

the carbon changes form, the grain changes. If we take a piece of annealed steel and heat it to a very little less than this critical temperature and cool it quickly, we find that it has not hardened, and the grain is unchanged. If we heat it a very little above this critical temperature, and cool quickly, we find it very hard and the grain fine. When cooled quickly from any higher heat the grain is coarser and on test we find the steel less hard. The decrease in hardness due to cooling from an excessive heat is more marked in the high than in the lower carbon steels.

The change from the Cementite to the Martensite form takes place instantly as shown in the accompanying photograph.



The results shown were secured in the following way. A piece of steel was nicked in several places so it could be easily broken. The piece was then placed on the top of a bright quick fire and heated on the end (A). The end shown at (B) was black hot when the piece was plunged into water. When cold, the steel was broken at the nicks. Beginning at (A) the hotter end, we find the grain finer and finer as we proceed toward the cooler end, until we come to the point (C) where the steel is exactly at the critical or hardening temperature. Between (B) and (C) the steel is not hot enough to harden, and we have the grain of the annealed bar. This demonstration shows that the change from the Cementite to the Martensite form of carbon takes place suddenly. If it did not there would be a gradual blending from the fine to the coarse while the sample shows a change so suddenly as to make a sharp line between the two, as seen at (C). If this surface is polished and tested for hardness with the Sclero-scope, we find that the patch between (B) and (C) is not hardened, while just at the right of (C) we find the maximum hardness.

If we heat a piece of steel, particularly if it is a high carbon steel, one hundred thirty-five point for example, to

a heat much above the critical temperature, we find that the hardness has dropped off while the grain is coarse and the steel very brittle. When heated to any point above the critical temperature, the carbon is in the Martensite form and if cooled suddenly it will remain in this form. If cooled slowly, it changes back to the Cementite form. In other words the change from the Cementite to the Martensite form takes place suddenly at the critical temperature. If cooled quickly from any temperature above this critical temperature, the Martensite form is retained and the steel is hard. The Martensite form of carbon changes back to the Cementite form on the application of heat but does so gradually. The change begins at about 400° F. and is complete at 700° F. As the carbon changes back to the Cementite form slowly the hardness decreases while the toughness increases. This is the process of tempering.

From the above, we see that it is very important to determine the critical or hardening point of steel. This is easily done by the use of the magnet or ordinary compass needle. It is well known that carbon steel loses its magnetic properties at a certain heat. This is the temperature at which the carbon changes form. We may then test steel with a magnet or compass needle, and when we find that the steel has become non-magnetic we know we have passed the critical point. If the testing has been done at frequent intervals as the heat has been raised, we may locate the point pretty accurately. Carbon steel should be hardened at the temperature at which it becomes non-magnetic.

Carbon steel may be forged at a much higher heat than the hardening heat. Steel will not be injured if heated no higher than the scaling point, provided it is treated properly afterwards. After forging, all steel should be annealed or at least let cool down to the black heat. Then bring the heat up very carefully to the critical point taking care that no part of the steel gets above this point. Even, thorough heating is very necessary. Always harden at the lowest possible heat, just above the critical temperature, and always on the rising heat.

SCIENCE DEMANDS RECOGNITION IN THE ARTS.

E. T. CLARAGE,
President of The Columbia Tool Steel Company.

In the "Engineer" published in London, England, under date of March 5th is an article in regard to High Speed Tool Steel in which appears this statement.

"Every maker now and then produces a tool which is far and away in advance of any other he himself has made. As far as he knows its composition is precisely the same as that of a score of others. It is therefore believed to be due to the treatment in hardening. There is no doubt a best temperature at which to plunge and since the heat in any case is excessively high, slight differences are only secured by chance."

This is very generous on the part of the "Engineer" to place all the responsibility on the workman and relieve the Tool Steel maker of any liability, but looking at it from a scientific standpoint, there may be something for the steel maker to consider.

These new High Speed tool steels are made by using certain alloys belonging to the Chromium group, but as far as we know, the old time practical steel maker has utterly failed to take into account natures laws of chemical combinations.

To illustrate, nature only knows two combinations of iron and oxygen. $Fe_2 O_3$ which is 42.857 parts oxygen to 100 parts of iron, and $Fe_3 O_4$ or 38.095 parts of oxygen to 100 parts iron.

Another common illustration is shown by carbon and oxygen. The only two possible combinations of which are C-O, or 133.33 parts of oxygen to 100 parts carbon, and $C\text{-}O_2$, or 266.66 parts oxygen to 100 parts carbon. These are the only proportions in which carbon and oxygen will combine chemically, and any excess of either element must exist as a mechanical mixture, that is, uncombined.

That these same laws control the combinations of alloys used in the modern High Speed steels, is true beyond question, although the tool steel makers as a rule have paid no

attention to the matter, and these alloys have been used indiscriminately.

The Hadfield manganese steel is a good illustration. Up to about 1% manganese the effect is beneficial. Above that percentage the strength of the steel decreases very rapidly, so that with a little over 2% manganese the steel is actually rotten.

After other experimenters had given up Manganese in the higher percentages, Hadfield went on up through the various percentages and discovered that with 3½% manganese considerable of the toughness returned. At approximately 7% it again showed an increase, and at between 13 and 14% manganese he produced the most wonderful metal the world has ever known. A metal so tough that it can be bent cold double on itself, at the same time it can not be cut by any tools as yet available.

It is evident that in certain ratios the manganese combined with the iron chemically. As the percentage of manganese was increased beyond the combining ratio, the excess amount existed in the uncombined or free condition, or really as an impurity like so much sand. When a point was reached where a chemical combination could be effected at the next higher ratio, the character of the steel changed accordingly.

The manufacture of carbon tool steels is a fairly simple art, tool steel being simply carbonized iron, and the stronger and purer the iron, the stronger the steel. It was not required of the steel maker that he bother his head with any of these complex propositions, but with the advent of the modern High Speed Alloy Steels the situation has entirely changed. The old shop rules and traditions which were sufficient in the past fall lamentably short under present day requirements. The introduction of these alloy steels has resulted in making the manufacture of tool steel one of the most complex problems known to metallurgy. The scientist finds himself face to face with new intricate problems. Chromium from eastern Europe, Manganese from Russia, Silicon from France, Vanadium from South America, Tungsten and Molybdenum from Spain, Australia and also from Colorado, in fact no part of the world is overlooked, and the search for steel making material is as wide and as thorough even as the search for gold.

The problem for the steel maker is not what action may be expected from any one certain alloy. It becomes a question of what the perfomance of this alloy will be in the presence of several other elements whose effects upon each other are profoundly potent. Because a steel with a certain percentage of an alloy gives splendid results, it is in no wise certain that increasing the percentage will produce better results. There are certain ratios or relative values that must be considered.

I am aware that this phase of the situation will receive very little favor at present among the tool steel makers themselves, as any progress along these lines means a vast amount of research. Nevertheless, these conditions exist, and must be met eventually.

The technical man must receive proper appreciation in the workshops of the world. Science cries out for recognition in stentorial tones that can not be longer ignored.

ENGINEERING APPLIED TO THE AUTOMOBILE.

D. W. KREIDLER, M. E., '11.

The growth of the automobile manufacture has never been exceeded, if parallelel, by any other industry. Though this development has taken place within a period of ten or twelve years, it is now one of the large industries of the country. One firm alone proposes to build forty thousand cars for the season of 1910. Several will build ten thousand, and a number, five thousand. The average retail price of these cars will certainly not be less than one thousand dollars. When we consider that the companies engaged in motor car manufacture now number in the hundreds, we have a slight conception of the capital handled. With the present rapid increase in the number of companies building cars, it is more than possible that there will be an overproduction within a year or two. This will probably cause a great slump in the industry, the reaction from which, will place the business on a firmer basis. The motor car has too many practical applications to ever fall as the bicycle did. It is only a question of time before the larger portion of the delivering, in the cities, will be done with automobiles. Besides the commercial cars, there should always be a steady demand for pleasure vehicles.

The design and manufacture of motor cars comes under the large head of Mechanical Engineering. The object of this article is to show, in a general way, that automobile engineering represents one of the very highest types of engineering work.

The problems involved in the design and construction of a motor car are peculiarly difficult. The successful automobile must be of light weight for a given power. This is of great importance because the wear on tires increases very rapidly with an increase in weight: [tires being one of the largest items, in the running expenses of a car.] The successful automobile should be safe, and comfortable, even at high speeds over rough roads. It should be capable of standing severe road shocks without undue strain, or misalignment of its machinery. This same machinery should run

quietly and smoothly. To the above qualities should be added that of beauty, both in finish and lines. Consider all of these qualities and then find any other machine more difficult to design than a successful motor car.

Taking up these points somewhat in detail, as they apply to the different parts of a car, let us consider first, the motor. A good motor should be light, powerful, quiet, and durable. To secure light weight, a refined design must be used in which safety factors are cut to a minimum. This feature is true of practically the entire machine. To accomplish this, stresses must be calculated accurately; or else a considerable amount of good judgment from past experience used. In either case, the design should be checked by means of a severe test of the component parts, followed with a test of the assembled car. Light weight is further attained by using materials best suited for each individual part. For example: aluminum for the crank case; alloy steel for crank shaft and connecting rods; the very best cast iron for pistons and cylinders. To secure maximum power, not only should the valves, cams, and parts be well designed, but the machine work must be as accurate as possible. To secure quietness of operation requires the best of workmanship, also well designed valve motions, having as little clearance as possible. The timeing gears must be cut and meshed accurately. Durability is obtained by having, in addition to the above qualities, accurately designed and well fitted bearings, together with an infallible oiling system. To illustrate what has been accomplished in motor design, it might be said that there are any number of motors weighing less than ten pounds per B. h. p. If it were not for the development of the light weight, high speed, automobile engine, it is doubtful if the airship would be enjoying its present success.

Let us next consider the transmission; [the mechanism of a motor car which gives different gear ratios between the engine and rear axle.] This should be light, strong and quiet. To obtain lightness; aluminum for the case, and alloy steels for the shafts and gears, are again made use of. It might be cited that the automobile has probably done more to develop high grade alloy steels, such as: vanadium, nickel, chrome, etc., than any other industry. Ten years ago a steel having a tensile strength of 100,000 pounds was considered

extraordinary, while now we have steels which show a tensile strength as high as 240,000 pounds.

Perhaps the greatest problems met by the automobile designer are those due to road inequalities. The stresses due to shocks received by a car traveling over a rough road at speed, are very severe, and difficult to calculate. For example, it is practically impossible to calculate the stresses to which the steering gear of a car are subjected when one of the front wheels strikes an obstacle. The greatest problems probably come in transmitting the power from the transmission to the rear axle. The usual practice is to bolt the transmission to either the car frame or the engine, and transmit the power through a shaft, having universal joints at each end, to the bevel gears located in the rear axle case. The rear axle must, of course, be fastened to the frame by means of springs, thus allowing the axle to play up and down, while the transmission remains fixed relative to the frame. This play of the axle relative to the car frame causes a change in the angles of the driving or propeller shaft at the universal joints. This, in turn, tends to cause an un-uniform angular-velocity of the propeller shaft. The motor, with its fly wheel and high speed, tends to continue rotating at a uniform rate, thus causing severe torsional strain in the propeller shaft. In the case of a single universal joint in the propeller shaft, as is sometimes used, the lack of uniformity is much greater than in the case of two. Similar difficulties are experienced in the case of side chain drive. This point was very well discussed in an article in the Horseless Age of December 15, '09, by S. Gerster.

In connection with the rear axle there is the problem of taking up the torsional stresses due to the reactions of driving and brakeing. As the car is driven forward, the reaction, due to driving through the bevel gears, tends to cause the axle casing to rotate in a counter direction to that of the wheels. Also, when the brakes are thrown on they tend to lock the wheels to the axle case, thus tending to rotate the same in the direction in which the wheels rotate. To prevent the axle case from rotating, the torsion must be taken up by means of a rod or tube rigidly fastened to the axle casing at one end and hinged to the frame at the other, so that the axle may be free to play up and down. Usually the driving force, due to

the tractive effort of the rear wheels, is transmitted through the springs to the frame. Thus the car is literally pushed by forces acting through the springs. In some designs, the propeller shaft has only one universal joint located at its forward end. In this case the torsion member takes the form of a tube which encloses the propeller shaft. In this scheme the rear springs may be shackled at both ends and thus a free spring action is obtained. This means, however, that the torsion tube must transmit the force which pushes the car, as well as take up the torsion. This tube must, therefore, act as a combined column, and cantilever beam. The size of torsion rods and tubes could be easily calculated for steady driving stresses, but it would be quite impossible to figure the greater stresses due to emergency brakeing or sudden engagement of the clutch, connecting the motor and transmission. For this reason, they are usually designed on the "cut and try" method.

In conclusion, we may say that the successful automobile must be a light, efficient, and dependable mechanism; capable of withstanding unusual stresses and abuse. Contrary to popular opinion, there are very few cars on the market which come up to these exacting requirements. What the industry needs, to improve the quality of cars, is a large amount of research work that will aid the designer. Already several of the engineering schools have taken up this work. It is to be hoped that all of the better institutions will soon follow their example. As the manufacture of motor cars is already one of the big industries of the country, the engineering colleges should support it as they have supported the railway, and other great industries.

THE MANIPULATION OF THE OXY-ACETYLENE BLOWPIPE.

HERBERT LUSCIUS WHITTEMORE, B. S.,
Associate in Theoretical and Applied Mechanics.

When it is necessary that a thing be of the greatest use, it is sometimes found that the smaller it is the better. For example, machine tools for finishing large castings and forgings are now, frequently, made as light and compact as possible. The overhead crane picks them up and carries them to the work, to which they are firmly attached, sometimes two or more to the same piece. Power is supplied by electric cable, flexible shaft, or air hose, and the work progresses more satisfactorily than was the case when the machine tool was a ponderous structure and carried the piece upon which it worked.

A more striking example of this use of the diminuitive is the development, in the last few years, of the oxy-acetylene blowpipe for welding and other work on metals.

As far back as we have any knowledge, welds have been made by heating the pieces in a fire to the proper temperature, then removing them and uniting by pressure. Usually this pressure is produced by hammer blows. Both the heating apparatus and the hammer, with its necessary anvil, must be of great size for large work. Now, however, the blowpipe, held in the operator's hand and as easily controlled as a garden hose, may be substituted for the older appliances in many instances. The reason that very large work is seldom done with the blowpipe, is that the cost is greater than for the older methods—a disadvantage which may, in time, be removed. It is probably true that the blowpipe will never replace the forge entirely, but it will furnish the means for performing, more easily and cheaply, certain operations, particularly on the thinner plates, say up to an inch in thickness. Many of these operations are, moreover, impossible by other means. In welding with the forge it is difficult or impossible to unite metals which pass quickly from a solid to a liquid state, such for example, as cast iron, so that forge welding is practically confined to

those which become soft or plastic before they melt, such as wrought iron or soft steel. When the blowpipe is used, pressure is unnecessary as the intensely hot flame melts the most refractory metals and, in the case of two pieces, material from each runs down to form a small pool of molten metal between them which, of course, unites them when cold. Due to this method of working, cast iron is frequently welded, and brass and aluminum are also successfully handled. The whole process of welding steel plates, for example, may be likened to the joining of two sheets of paraffine or sealing wax which could be united by heating with a small gas burner from above so that the material would flow together across the seam. The molten steel behaves much like the hot wax except that it does not become so fluid.

The oxy-acetylene blowpipe is an outgrowth of the ordinary blowpipe supplied with air and illuminating gas. With any blowpipe, the necessary elements to be supplied are the oxygen and the combustible gas with which it unites. Given amounts of these will always develop the same amount of heat but the temperature of the flame will depend upon the total amount of gas to be heated. When air is used, the nitrogen, which dilutes the oxygen, adds nothing to produce heat but absorbs heat in passing through the flame and so lowers its temperature. If oxygen is substituted for air an increase in the flame temperature will be obtained, and the temperature may be raised still further by replacing illuminating gas with some other gas having a higher thermal value per unit of volume, such, for example, as hydrogen or acetylene.

The oxy-hydrogen blowpipe has been used extensively and will weld steel and other metals if the thickness is not too great. The temperature obtained is about 4000 degrees F. This is above the melting point of mild steel which is 2687 degrees. It must be remembered that the hot metal directly under the blowpipe is surrounded by a comparatively large amount of cold metal which is rapidly absorbing heat due to the fact that metal is a good conductor. To melt the metal at the surface, then, it is necessary to supply heat faster than it is conducted away. This the

oxy-hydrogen blowpipe is unable to do if the plates are thick.

The oyx-acetylene blowpipe, due to the much higher thermal value of acetylene compared with hydrogen, has a flame temperature of about 6000 degrees F. which allows the surface of metal several inches in thickness to be readily fused. The objection that such a temperature overheats the metal and destroys its useful properties, is met with the claim that the heat is conducted from the surface so rapidly that none of the metal is ever heated much above its melting point and that the high temperature of the flame permits work to be done more rapidly and perfectly as fusion can be easily produced.

Although there are a number of forms of oyx-acetylene blowpipe on the market, they are probably much alike, except in minor details, and doubtless good work can be done with any of them. One of the pioneers, if not the first successful design, is that of Fouche which is shown in Fig. 1. This particular size is intended to weld steel plates up to one quarter inch in thickness; for this work six interchangeable heads are provided. The head is the portion C-D in Fig. 1, any one of which may be easily fitted to the handle B-E. Each head is adapted for one comparatively small range in thickness of metal to be welded.

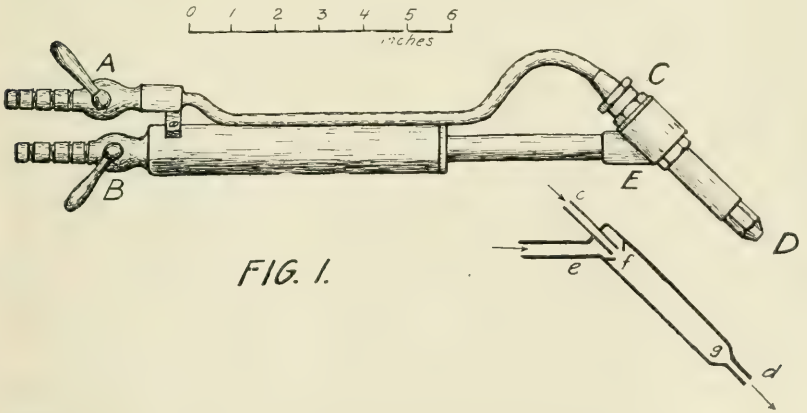


FIG. 1.

The acetylene is supplied through cock B, and the oxygen through cock A. Rubber hose connects each cock with

the generator or supply tank so that the blowpipe may be freely moved as the work requires. The pressure of the acetylene and of the oxygen is controlled by automatic regulators which maintain a certain constant pressure in each hose. This varies somewhat with the size of blowpipe and other conditions.

A diagrammatic outline of the construction of the blowpipe head C-D, is shown at c-d, Fig. 1. The oxygen enters at c and the acetylene at e. They both enter the mixing chamber at f and pass out through the tip of the blowpipe g-d to the air where combustion takes place.

With the proper tip in place for the work to be performed and the gases supplied under their proper pressures, the workman turns the acetylene on full at cock B and when its characternstic odor is detected at the tip D ignites it. The flame, which is much like A Fig. 2 in appearance, is pale or colorless close to the tip but becomes luminous at its outer end, much like an ordinary gas jet. Clouds of black soot can be seen rising beyond the outer end of the flame. The oxygen is then admitted by cock A Fig. 1 when the flame, previously quiet, gives a hissing sound and shortens as at B Fig. 2. The "first cone," as it is sometimes called, 1, B Fig. 2, is perhaps a quarter of an inch long and dazzlingly white like an electric arc. The workman should wear large colored goggles to protect his eyes from this intense light. If this is not done, not only is it almost impossible to see distinctly enough to properly direct the flame but the strain on the eyes will cause flashes of light to appear on closing them, for an hour or more afterwards, and, if continued, probably result in injury. If the flame, B Fig. 2, is viewed without the goggles, it has a somewhat blurred outline, but through them, the "first cone," 1, presents the hard, rigid appearance of a white-hot cylinder of metal having a semispherical end. The "second cone," 2, is luminous but less so than the first. Its outline is somewhat indefinite or feathery, especially at the tip. Beyond these is a pale blue flame, 3, of indistinct outline.

If the acetylene, which is being supplied in excess, is reduced in amount by partially closing cock B Fig. 1, the "second cone" shortens and then disappears, leaving only the "first cone," followed, of course by the pale flame as be-

fore. The flame is now properly regulated for welding or other work, and care should be taken that this appearance is maintained while the blowpipe is in use. If the amount of acetylene is reduced too much the "first cone" shortens gradually and appears to become more conial in shape. The angle x of the pale flame, 3, also increases quite noticeably, D Fig. 2, and the whole flame "sputters."

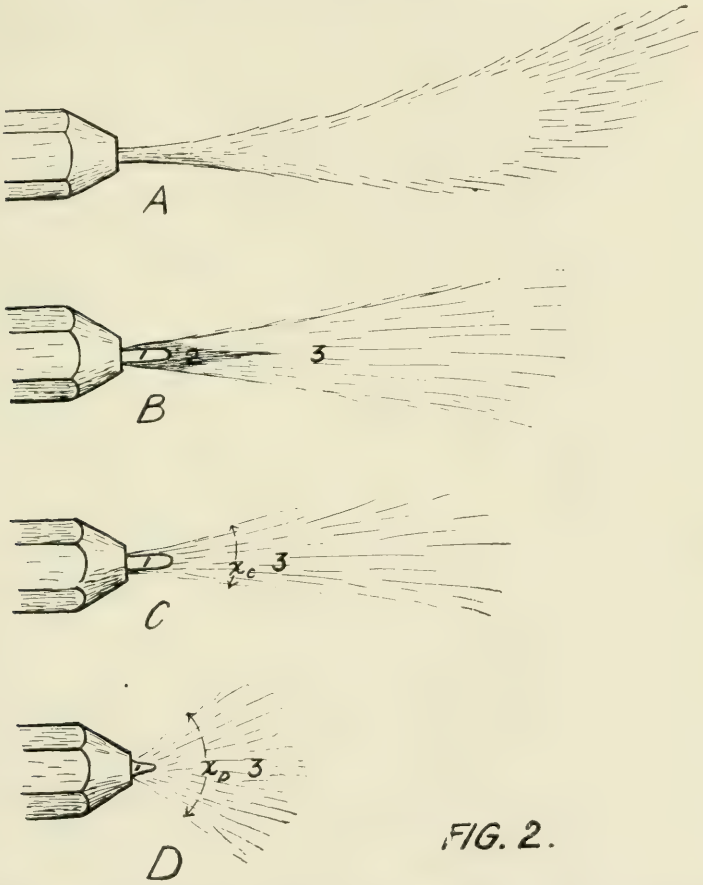


FIG. 2.

Theoretically 2.5 volumes of oxygen should be supplied for every volume of acetylene to produce perfect combustion, but, in practice, the ratio is only about 1.7 to 1. Under these conditions the carbon in the acetylene unites immediately with the oxygen, producing the "first cone." Much

of the hydrogen passes on and unites with oxygen from the air to form the pale blue flame. The highest temperature is at the tip of the "first cone," as can be readily proven by noting the rapidity with which it produces fusion of metal with which it is in contact. It is, therefore, used in welding. The pale flame, of much larger volume, acts as a transparent blanket to prevent the too rapid loss of heat from the "first cone" and adjacent metal and, more important still, to prevent the oxygen of the air from oxidizing the hot metal.

The striking change in the appearance of the flame, as the proportion of oxygen to acetylene is varied, is said to allow the proper regulation to be effected with great precision, as a slight change from the proper proportion makes a decided change in the appearance of the flame. With this style of blowpipe, if after proper regulation is obtained, work is continued for some time, it will be found that the amount of acetylene required is somewhat increased. This is probably due to the increase in the temperature of the blowpipe. It is well to adjust the amount of acetylene from time to time, which can be most conveniently done, perhaps, by admitting an excess and then reducing it to the proper amount.

Interruption of the work, momentarily, may not only occur while regulating the flame but also by "back firing" or ignition of the gases within the mixing chamber f-g Fig. 1, where they continue to burn. To understand this we must remember that we have in the mixing chamber an explosive mixture and it is its explosion which causes the snap or crack when the flame "back fires." If this mixture were in a small tube and ignited at one end, it would be found that the explosion would be propogated along the tube at a perfectly definite rate and would not occur instantaneously the whole length, as might be supposed. If, now, the mixture flows through the tube at a rate slightly greatly than that of the explosion, combustion will take place quietly at the outer end of the tube just as it does at the tip of the blowpipe. The reason, then, that "back firing" does not occur under ordinary conditions, is that the explosive mixture is flowing out through the blowpipe tip, from g to d Fig. 1, at a greater rate than the propogation of

the explosion from d to g. The only reason for "back firing," then, is a reduction of the velocity of the gas in the tip. If a metal plate is held perpendicularly to the flame and gradually brought toward the tip, a point will be found, which, if passed, will reduce the velocity of the gas and soon cause "back firing." Theoretically this point is one quarter the diameter of the hole in the tip from it. Due to the shortness of the "first cone," it is not unusual, in working with the blowpipe, to pass the tip too close to the metal, which will result in "back firing"; or, if the flow his been cut off quickly and completely the result would be to extinguish the flame. When "back firing" occurs, the gases continue to burn inside the mixing chamber, probably at f Fig. 1, as oxygen from the air is unnecessary, at least for incomplete combustion. While this heats the head of the blowpipe, and is, therefore, undesirable, it is not particularly dangerous because an explosion can not continue along either the oxygen or the acetylene passages which are separate from this point. As oxygen is, usually, under higher pressure than the acetylene, there is the possibility that a complete stoppage of the tip for a considerable time would cause the oxygn to "back up" into the acetylene passages and possibly into the acetylene generator or tank. To prevent such a dangerous occurrence, the acetylene is passed through a special "back pressure valve" placed as near as possible to the blowpipe. This automatically opens to the air if the direction of flow through it is reversed; i, e, from the blowpipe toward the acetylene generator. When "back firing" occurs the flame inside the mixing chamber can be extinguished by shutting off the gases. The blowpipe can then be relighted as at first. A small acetylene gas jet is frequently provided, in the pipe supplying acetylene, for this purpose. It is kept constantly burning while work is in progress. Another and quicker way to extinguish the "back fire" is to close the tip for an instant. This will increase the pressure in the mixing chamber and stop the flow of at least one of the gases and so make further combustion impossible. A convenient method of stopping the tip is to brush across it with the palm of the hand or finger. The tip is seldom hot enough to cause inconvenience if the contact is only instantaneous. If the metal is

still red hot after the "back fire" is extinguished, the blowpipe may be relighted by directing it aginst the weld.

Usually the acetylene is supplied under a pressure which is determined by the type of generator, etc., and so can not be readily altered. In the case of the oxygen, however, which is usually stored under pressure in steel bottles, the pressure may be varied as desired over a wide range. Each size of head in the Fouche blowpipe requires a different oxygen pressure which can be varied somewhat at the wish of the operator. If this pressure is increased too much, the supply of acetylene, which can not be varied, will be insufficient to allow proper regulation of the flame and, usually some excess should be available as the blowpipe heats. If on the other hand, the oxygen pressure is reduced too much, while the proper flame regulation can be obtained readily, it will be found that "back firing" is of such frequent occurrence that satisfactory work is impossible. This is due, as previously explained, to the low velocity of the gas through the blowpipe tip. It is this tendency to "back fire" which prevents a blowpipe head from being used for smaller work than that for which it is intended.

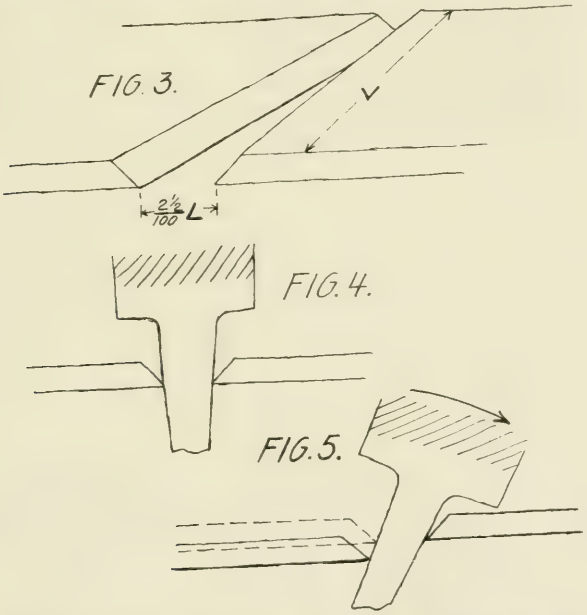
If the blowpipe becomes overheated, there is also an increased tendency to "back fire." When this becomes troublesome, the blowpipe may be cooled in water. It is preferable to extinguish the flame and leave at least one of the gases flowing to prevent water entering the blowpipe and clogging the passages temporarily.

Should the tip become partially clogged by molten metal during the progress of the work, (made apparent by the irregularity in the shape of the flame) it may be cleared with a piece of soft wire, but care should be taken that the size of the hole is not increased.

The effect of the gases upon the workman is of interest, at least to him. While oxygen probably has no bad effects in the quantities which he would breath, the acetylene has a very noticeable effect. The giddiness produced by a few inhalations of it will make anyone careful to avoid a repetition of the experience. *Z. f. Calcium Carbid* reports that four persons inspecting an acetylene generator, noticed an unpleasant odor and left the room. After being ten or fifteen minutes in the open air, each became unconscious. Upon their recovery,

the doctor explained the highly poisonous nature of acetylene gas. The gas produced by the blowpipe flame, consisting as it does largely of carbon dioxide, is also injurious in large quantities. For this reason, as well as to avoid the accumulation of an explosive mixture in the room, it is well to have a current of fresh air where the work is carried on.

In welding steel, which is the only material to be considered here, no flux or other foreign substance is required. If the sheets are thin, say one sixteenth inch thick, they may be placed in the position they are to occupy and fused together along the joint with the blowpipe. If they are practically in contact their full length, it will be found after work has proceeded a short distance, that the edges are crowding to-



gether with sufficient force to cause the plates to warp and buckle in a most surprising way. This is true of all thicknesses of plates and is caused by the contraction of the metal in the weld in cooling from the molten state. It may be avoided by placing the edges of the plates in contact where work is to start and with a considerable distance between them at the other end of the joint. This distance, experience

proves, should be about 2½ per cent of the length of the weld. If this is done it will usually be found that the edges will come together under the blowpipe as the work progresses.

When the plates are thicker, say one quarter inch or more, the blowpipe would fail to melt the metal for the entire thickness, so it is customary to bevel them at an angle of about 45 degrees, Fig 3. This allows the blowpipe to weld the edges in contact at the bottom of the groove first, then the thickness is gradually increased to that of the plates by fusing in additional metal. This "filler" may be iron or steel wire or strips of small cross sectional area so that it will melt readily when placed in the blowpipe flame. While strips, cut from the plates to be welded, may be used, wire is more convenient. Very soft steel or wrought iron seems to give the best results. If the diameter of the wire is too small, several strands may be twisted together.

Any way of handling this wire, which is convenient for the workman, may be used, but Mr. Fritze's method will probably prove satisfactory to many. He cuts off the length which can be conveniently handled, say six feet, and coils it into a rough ring about three inches in diameter so that it can be grasped easily in the left hand. The projecting end, about ten inches long, is melted away as required and as it shortens, more of the wire is unwound from the coil by pressing the projecting end against any firm support, without removing the coil from the hand or delaying the work. The coil forms a handle for the projecting wire and gives rather better control of it than is otherwise the case.

The blowpipe is held usually in the right hand and preferably at such a point that it balances without any wrist effort, which quickly becomes tiresome. The hose should lead straight from the blowpipe and may be supported, if convenient, to avoid drag or twist on the blowpipe.

If the plates tend to crowd too closely together as work progresses, a wedge of some kind, often the tang of a file, is used to keep them apart. This is also useful, if they tend to overlap, in bringing them again into the same plane. See Fig. 4 and 5.

We now come to the actual work of welding, to which the above is merely preliminary. The skill of the operator is an important consideration, especially in difficult work, such,

for example, as the internal repairing of marine boilers where the work is done overhead, when necessary, while the workman lies on his back. There are ports on the Mediterranean where such repairs are frequently made. Still, ordinary work requires no great amount of practice and unskilled workmen after a few days training, are employed on welding in some shops.

In starting, the blowpipe is swung from side to side across the joint where the weld is to begin, for a distance of perhaps half an inch. The tip of the "first cone" is kept about in contact with the metal which first becomes red hot, then melts at the surface. This molten metal from the sides of the groove tends to flow downward, but being somewhat viscous requires the blast of the blowpipe flame, in many cases, to blow it downward and unite it with the molten metal on the other side of the seam. The motion of the blowpipe from side to side or in small circles helps this greatly, and it also heats a larger area of metal than would be possible with the blowpipe stationary.

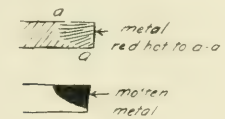


FIG. 6.

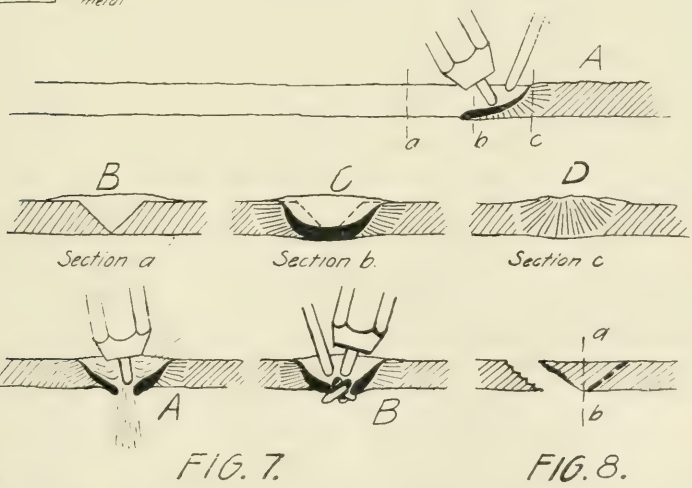


FIG. 7.

FIG. 8.

When the bottom of the groove is thoroughly molten, material is added from the filling wire to bring the thickness up

to that of the plates. This is done gradually, when the weld will appear somewhat as in Fig. 6. A longitudinal section through the weld is shown at A and sections through the weld at various points at B, C and D. When the bottom of the groove is well united, as at C, care should be taken not to heat the metal too highly, as, aided by the pressure of the blast from the blowpipe, it may fall out leaving a hole as at A Fig. 7, and the blast will quickly enlarge it by melting away the edges. When this occurs, the edges should be kept molten by passing the flame back and forth across the opening and metal added by pushing the filler into the hole and fusing off a short piece. This should be repeated rapidly until the hole is fairly well stopped, then the flame directed onto the place until thorough fusion takes place. Metal is then added, a little at a time, to bring the surface of the groove up to that of the plates. It is said that playing the flame onto the filler directly will overheat the metal so it is well, perhaps, to bring the filler into contact with the molten metal of the weld, then melt off the required amount by a few passes of the flame over the filler.

Probably the cause of most failures to produce good work is that the filling has been added where the metal in the weld is not thoroughly molten. While such metal will adhere quite firmly, the strength is much less than for the molten metal after cooling. If such a defect exists in a weld subjected to a tension test, it will fail along the original bevel Fig. 8, which may still show the tool marks on the fractured surface. This may only extend over a small area, each side of which the metal will separate perpendicularly to the surface of the weld, a-b Fig. 8.

If the blowpipe is held as shown at A Fig. 6, the blast from the flame will assist considerably in piling the molten metal up toward the higher side of the weld c, which is made easier by setting the plates at a slight angle upward to the left. About an inch rise per foot of weld is considered sufficient.

There are two rather distinct ways of handling the addition of filler material. In the first the bottom of the groove is joined for perhaps a quarter or half an inch, then filler added as fast as convenient and worked into the sides of the groove by melting material from them. The metal then forms

a little liquid pool perhaps half an inch in diameter. This when level with the surface of the plates is allowed to cool while the blowpipe is used to join the bottom and form a new pool just ahead which will overlap, slightly, that just completed. In the second, the slope of the metal on the advancing face of the weld, is maintained at about the same angle by adding filler equally from top to bottom. The bottom meanwhile is not allowed to advance faster than the weld as a whole. It is claimed that this is much the preferable method, especially if material is added frequently in small quantities by brushing the filler over the molten metal through or close to the flame. It is advisable also to work with the blowpipe at the greatest distance from the metal which does not interfere wih the progress of the work. After the work is once well sarted it will be found that the tip of the flame need seldom or never touch the surface of the metal. This will avoid overheating the metal, if that is possible.

When material is first added to the weld it forms a slight mound which spreads and unites with the weld at its edges as the flame is directed upon it. At first also it appears covered with irregular spots and figures which are much more fluid than the metal just beneath them. They appear to be more luminous than the metal itself which seems only red hot by comparison. These spots collect into small globules under the action of the blowpipe and are driven back by the blast to the cooler surface of the weld. Probably this is largely iron oxide or "mill scale" from the surface of the filler wire. Cleaning the surface of the wire reduced the amount appearing in the weld very noticeably. It can hardly be a desirable element in the weld, whatever its nature, and so should be driven away as much as possible before adding more filler.

The outline of the method of handling the blowpipe given above, which is based upon experience gained through practice as well as reading, should be considered rather in the nature of suggestions than as proven facts. Each workman will develop methods which are satisfactory to him, and the instructions available to any person who has no more experienced instructor to help him are very meager and indefinite. From the nature of the subject, sketches are difficult to make accurately, but they convey ideas which are at least reason-

ably definite. These diagrams are the first which the writer has seen showing the actual welding process. If they prove a help to someone doing such work, they will have served their purpose and possibly encourage others with more experience to illustrate their ideas. The fact that many welding outfits are sold by the manufacturers with only written instrucion for the operators, shows that personal instruction can be dispensed with successfully. After the fundamental ideas are grasped, practice is doubtless the great factor in producing good work.

The writer's practical experience with the blowpipe has been gained while making a series of tests in the Laboratory of Applied Mechanics, University of Illinois, to determine the physical properties of oxy-acetylene welds in steel plates. This is a matter of importance due to the increased use of the blowpipe commercially and the very meager and unsatisfactory information available regarding the strength etc. of such welds and the conditions necessary to produce the best results.

THE RELATION BETWEEN WEIGHT AND CAPACITY OF PRIME MOVERS.*

RALPH E. HOLCH, M. E., '10.

The great amount of material going into the construction of prime movers brings up the question of how or where a saving might be made. If there is some relation between weight and capacity, this will furnish information in answering the question. Economy of the medium used in the engine, or of steam versus gas or water, the transportation of fuel, or other considerations might decide the question against economy of material used in construction of prime movers. But so many are made and so many are still to be made that the question should be of importance to all interested in the generation of power.

Most of the data considered was obtained from American manufacturers, but some was taken from technical papers. All ratings of prime movers were reduced to brake horse power by assuming a general mechanical efficiency of ninety percent. Weight per brake horse power was then found by dividing the weight of each machine by its rating.

To plot curves and let each engine represent a point was found unsatisfactory, for the weight of engines, even those in the same series of sizes, do not follow closely any given law. If plotting were done this way, the points would form a cloud rather than follow a line. It was found better to average the figures for engines of a class and within a short range of capacity, and use these averages in plotting curves.

It was also found that there is a great variation in total weight and in weight per horse power of prime movers of the same capacity and class, but of different design and built by different makers. This at once indicates that there is but little close relation between weight and capacity, tho theoretically there might be a close one. To make matters more involved, it was found that for a single design built in a series of sizes by one maker, there is the same lack of any law. One engine has a given weight, the next size larger may increase

*Extract from thesis by S. B. Wright and R. E. Holch, presented at the University of Illinois in June, 1909.

but little, and the next a great deal. In many catalogues, two consecutive engines of a series would be quoted as having the same weight. In some cases three consecutive engines would be treated in the same way, and in a few four. This is probably due to the use of standard parts which some makers adapt to two sizes, some to three, and some to four, and partly to the inaccuracy in the production of castings of uniform weight. Some manufacturers advance the weights of engines of a series by the same amount altho the capacity increase is not constant. This seems to be a simple guess on the part of the maker. Some, tho few, go so far as to record the actual weights down to the ten pound point of accuracy.

It was found that there is a more or less sharp bend at the lower end of the curves plotted. This portion of the curve represents engines of small power. The upper part of the curves was as a rule more straight. The bend in the curves for reciprocating engines is quite sharp and is due perhaps to the extra weight of small machine parts, which, for small engines, are heavier than would be necessary if designed for strength only. This extra weight on the small engine is a smaller percentage of the total than is the case with larger ones. It is seen that the weight per horse power would be larger for these smaller engines than for the ones further up on the curve. Small engines are built for higher speeds than larger ones. Therefore, the frame must be heavier in proportion to prevent violent vibration. A similar bend occurs in the curves for marine gas engines, vertical oil engines, and water turbines, but it is in the other direction. Why this reversal should be is not clear. Neither is it clear why the bend in the curves for water and steam turbines should be in opposite directions as the machines are so much alike in construction.

It was found from the curves that turbines, water or steam, are much lighter per horse power than reciprocating engines. This is due mostly to the difference in the speeds used and the necessity for a fly wheel on reciprocating engines. In late years the advance in the use of high speeds in machinery has made the building of turbines not only useful but necessary. The invention of the centrifugal pump and air compressor has made a great field for the turbine.

The centrifugal pump of series design has been made to

lift water nearly two thousand feet. The fan blower has been made to furnish air at ninety pounds pressure. Both of these machines are of small size, and being driven by steam turbines, which are also small, it is easy to see that a great saving of material can be made by the use of such combinations. There is little question as to the superiority of turbines in electrical plants; and they are proving of great value as substitutes for reciprocating engines in marine work. In the latter service, a saving of space is also of prime importance. There is little doubt that in the future, possibly the near future, there will be a large saving of materials by the use of turbines in the place of blowing engines, recipracating engines, for pumping service, and the like.

The first thing of importance found in the study of this subject is the fact that the relation between weight and capacity of prime movers is very unstable tho there is a general tendency to follow some law. Even in a series of engines of the same design no law is closely followed. Marine gasoline, vertical oil engines, and water turbines increase in weight per horse power with the capacity of the unit. All other types decrease in weight per horse power as the capacity increases. Very large gas engines tend to increase in weight per horse power again after the ordinary sizes are passed. The greatest variation in the relation occurs for all types among the smaller units. The lightest prime mover is the steam turbine. The heaviest is the single acting horizontal gas engine. The latter type also uses more floor space than any other type, and the horizontal velocity steam turbine uses least.

It might be said that the increased use of turbines during the last few years would make the weight per horse power of the total number of prime movers in use less. But since the gas engine is the heaviest type, and its use is increasing at a rapid rate, the tendency may be thereby balanced or even made to go the other way. This would depend upon the relative use made of the two types.

The following tables give in round numbers the range in weight per horse power for the range of horse power represented.

Type of Prime Mover	Range of Horse Power	Range of Weight per Horse Power
Steam Engines—		
Simple Automatic	10— 1000	100— 60 lb.
Compound Automatic	100— 800	150— 75
Simple Standard Corliss	125— 200	200— 125
Heavy and Extra Heavy Corliss	150— 1000	150— 125
Locomotives	750— 2000	200— 150
Hot Air Engines	0— 7	17000—5000
Gas and Gasoline Engines—		
Four Cycle Horizontal	5— 150	110— 70
Four Cycle Vertical	9— 200	425— 200
Marine	10— 100	60— 110
Automobile	20— 60	16— 12
Motorcycle	3— 6	25— 12
Airship	25— 75	7— 2
Vertical Oil Engines	0— 175	80— 110
Steam Turbines—		
Velocity	0— 300	80— 30
Curtis	0—18000	50— 25
Pressure Horizontal	0—10000	110— 20
Water Turbines	0— 1500	5— 15

DISCUSSION OF SALIENT PROCEEDINGS RELATIVE TO THE ILLINOIS SPECIAL ASSESSMENT LAW.

J. P. MORGAN, B. S. IN C. E., '08.
City Engineer, Urbana, Illinois.

When an Engineer or Attorney starts his first improvement under the Illinois Special Assessment Law, he is apt to underestimate the difficulties in his way. One experience, however, is usually sufficient to impress upon his mind the responsibilities which rest upon him and which must at all times be exercised.

If public works are to be constructed in a satisfactory manner, and if the bonds used for subsequent payment are to be acceptable to the bond examiner, the Engineer and Attorney must work in harmony and at least one of them should have had previous experience in the handling of local improvements. Each official should have a more or less definite knowledge of the duties which the law imposes upon his colleague, but it is a dangerous move for either to exceed the limits of his authority. The situation presents problems and difficulties which require the knowledge of two professions and it is not often that one man is fitted to handle both. Consequently, a division of the responsibility between the engineering and legal departments will tend to decrease the number of errors and save misunderstandings which may otherwise cause the labor of both departments to be lost. There is a case of but a few months standing in which the Engineer took the Attorney's business into his own hands, gave notice of a public hearing shorter than was required by law, and thereby started the improvement on a road which led to contention in the courts and ultimately to the rejection of the bonds.

Estimates for an improvement should be made with the thought always in mind that they must not vary substantially from the actual values. The larger items should be carefully checked and, so far as possible, all chance of serious error removed. It is astonishing to learn of a discrepancy amounting to nearly twenty-five per cent of the estimated cost of a thirty thousand dollar improvement, yet less than a year

ago, such a case was contested before a County Court. It is needless to state that the promoters were forced to acknowledge their inconsistency and withdraw their proceedings.

Different Attorneys require various amounts of detail in the Engineers estimate, according to their interpretation of the local improvement law. For instance, some require a brick pavement to be considered under the following heads —1. Excavation, 2. Foundation, 3. Sand Cushion, 4. Brick, 5. Filler; while others want only the two items—1. Excavation, 2. Pavement. Even more detail is sometimes demanded, as in the case of a certain property owner along the line of a proposed improvement, who objected to the estimate because items of labor were not listed separate from those of materials. Those who pay for the improvements are entitled to know, so far as practicable, for what each dollar of their money is expended. However, it is worse than useless to introduce a very large number of units because some of the items are necessarily inexact and offer loopholes for argument and attack.

The plans for a local improvement, made by the Engineer, approved by the Board of Local Improvements, the City Council and the County Court, must be carried out substantially as made. This requirement in the Special Assessment Law is of course necessary, and yet it is the cause of more or less confusion. A definite interpretation of the word "Substantially" is a difficult matter and an Engineer is sometimes very much at a loss to determine just how far he may go and yet be within the bounds of the law. The writer had an experience of this kind not long ago. Along the line of an improvement, two bridges were to be built according to plans calling for rather expensive structures. Because improvements and changes in the channel of the stream were contemplated, it became the opinion of the Board of Local Improvements that the position of the bridges should be changed and that the cost of construction should be lessened. The Engineer did as ordered and, as a consequence, one of the property owners refused to pay accrued interest on his assessment and threatened to take the matter to the courts. It did not seem probable that his claims would be upheld but the procedure referred to was exceedingly undesirable and the affair caused much anxiety until a peacable settlement was finally effected.

It is occasionally proposed to change the grade of a pavement or sewer and slight changes are sometimes advisable. Any change in the character of an improvement, however, which would be noticed upon casual comparison of the plans with the construction, should be carefully considered and usually strictly avoided. A very good method is to adhere closely to the plans at all times unless, by so doing, the general character or appearance of the work will be seriously damaged or affected.

To Engineers as well as to Attorneys, a book written by Mr. A. H. Baer for the National Brick Manufacturer's Association will give much valuable information as to forms for estimates and procedure. This book sets forth clearly and concisely the various steps from start to finish of a public improvement as based upon the Special Assessment Law and aids materially in avoiding many fatal errors and omissions. Constant watchfulness is essential through all the stages of the work, for as Mr. Baer states, "the procedure is one exceedingly vulnerable to successful attack, unless it is, in all respects, essentially correct; and if successfully assailed, as a general rule, causes the greatest embarrassment to the municipality and the deepest mortification and humiliation to those concerned as its proponents."

EXPERIMENTS ON BUILT-UP COLUMNS.

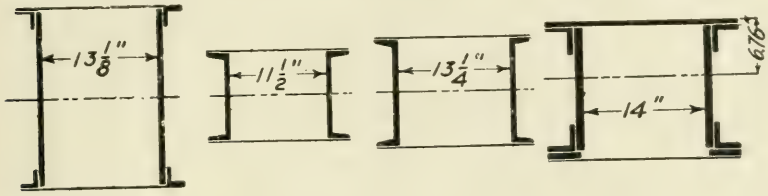
HERBERT F. MOORE, B. S. M. M. E.
Assistant Professor of Theoretical and Applied Mechanics.

During the past two years there has been carried on in the Laboratory of Applied Mechanics of the University of Illinois a series of tests on the strength of built-up steel and wrought-iron columns. The number of columns tested has not been large but the series has been unusual in the careful investigation of the intensity of stress existing in the various parts of the columns when under compressive load. During the manufacture and erection of built-up columns, channels, lacing bars, and other members become bent in the process of aligning the column, and in shipping and unloading the columns slight local injuries are sometimes caused. One of the objects of this series of tests was to determine whether in a column under load such kinks and bends caused any marked irregularity of stress distribution.

In the study of the behavior of the parts of columns under load extensometers were attached to various parts of the column and the deformations produced over short guage lengths noted for a load within the elastic limit of the column. The extensometers were so placed that the distribution of stress over the section of flange members was determined. Deformations in flange members and lacing bars were thus measured. A special extensometer was designed for this work.

Tests of columns were made in the 600,000 lb. testing machine of the Laboratory of Applied Mechanics, and there were also tests made on compression members of an Illinois Central railroad bridge across the Sangamon river at White Heath, Illinois. The columns tested in the testing machine comprised (1) a special test column (Column No. 1) made up of two built-up channels laced together, and (2) four wrought-iron bridge posts from a Chicago, Burlington, and Quincy railroad bridge which had been replaced by a heavier structure. In column No. 1 the parts were made of very thin angles and plates so that the effect of kinks, bends and other imperfections of manufacture would be accentuated. The

wrought-iron columns were made up of two channels laced together and were of ordinary proportions. The columns tested in the railroad bridge at White Heath were of usual proportions and comprised two posts made up of channels laced together and an upper chord made up of two built-up channels and a cover plate. Fig. 1 shows the cross sections and Table 1 gives the general dimensions of the columns.



a. *b.* *c.* *d.*

FIG. 1.—CROSS SECTIONS OF COLUMNS.

a. Column No. 1, 2 Plates, 20″×⅜″, 4 angles 2″×2″×¼″.
b. Wrought Iron Posts, Nos. 2, 3, 4 and 5, 2—10″ channels, old model.
c. Posts, White Heath Bridge, 2—12″ channels, old model.
d. Upper Chord, White Heath Bridge, 2 Plates 14″×$\frac{11}{16}$″.
4 Angles 3½″×3½″×$\frac{7}{16}$″, 1 Cover Plate 21″×$\frac{3}{16}$″, 2 Flats 4″×¾″.

In the tests in the testing machine it was necessary to move the extensometers from place to place, and to apply and remove a given test load for each location of the extensometers. This necessitated a very large number of loadings of each column and a still larger number of instrument readings for each test. After the stress distribution throughout the column had been investigated by this method the column was loaded to destruction and observations were taken of the deformation of those parts in which the stress distribution tests had shown the intensity of stress to be a maximum. In the tests of columns in the railroad bridge the load was applied by means of a test train which was run to a certain point on the bridge and then run off again. The deformation of parts of the bridge columns was measured by extensometers. In the bridge tests as well as in the laboratory tests it was necessary to move the extensometers from place to place. In all tests the deformations at any place were checked by taking several measurements.

The results of the tests of stress distribution show that in the case of a column built up of thin pieces—such as Col-

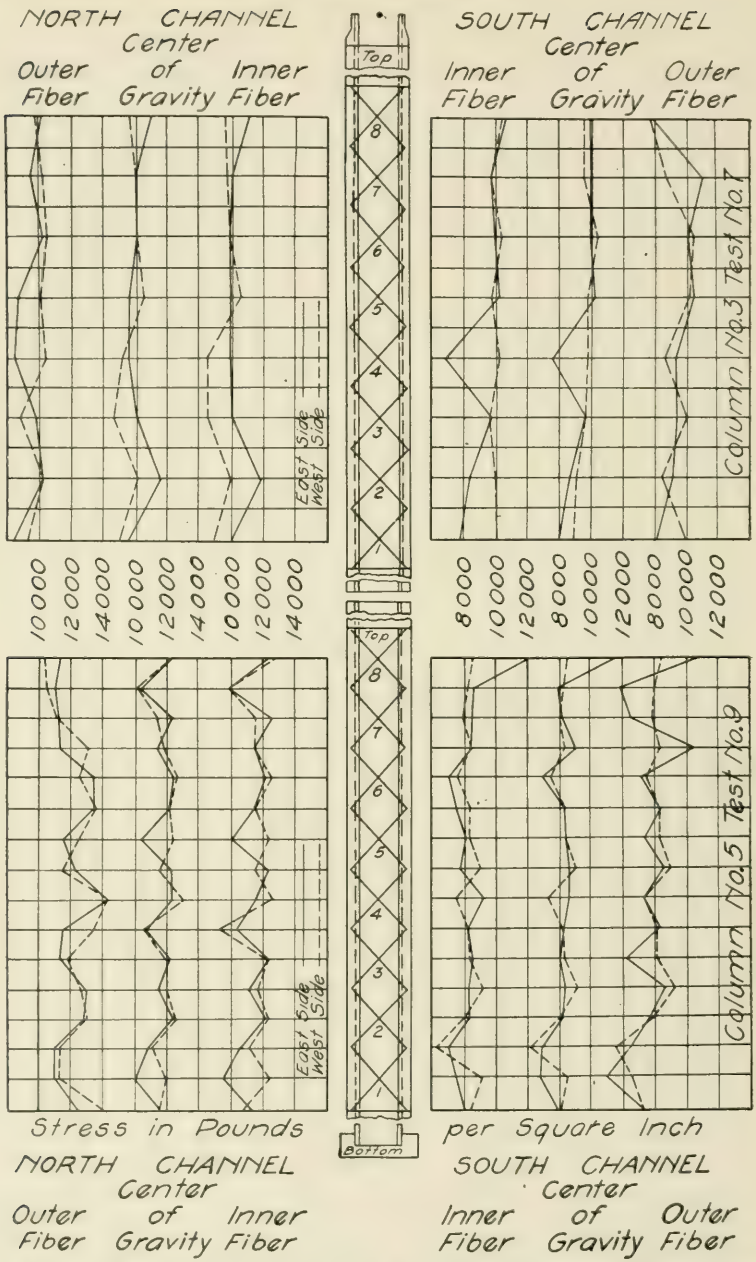


FIG. 2.—STRESS DISTRIBUTION IN COLUMN NO. 5 UNDER AN AVERAGE COMPRESSIVE STRESS OF 10,000 LB. PER SQ. IN.

umn No. 1.—imperfections due to processes of manufacture and erection may produce a greater variation in distribution of stress across a section than is produced by the bending action of the column as a whole. In the stocky wrought-iron columns tested in the testing machine and in the posts of the bridge, the effect of imperfections of fabrication was apparent to a somewhat less degree, but the effect of end conditions was notable as was shown by a gradual change of maximum stress from one corner at the top of the column to another corner at the bottom. In the upper chord of the bridge, which was made up of two built-up channels and one cover plate, the stress distribution was more nearly even than in any other column tested. Fig. 2 shows a stress distribution diagram for Column No. 5 under an average compressive stress of 10,000 lb. per sq. in. of cross sectional area, and Table 2 shows the greatest proportional stresses observed in any parts of the columns investigated. Attention is called to the irregularity of stress distribution as shown by Fig. 2, and to the large excess of maximum over average stress as shown in the tabulated results. In this connection it should be noted that the slenderness ratio l/r of all columns tested was comparatively low.

From the results of the above tests and of other tests, notably those of Professor Lilly of Dublin, it would seem that the column formulae in common use are imperfect in that they place so much stress on the length of column and in that they contain no term dependent on the thinness of component parts. In this connection it may be noted that while a small kink in the channel member of a column may seem to have but little effect on the column as a whole, it may greatly increase the local stress in that channel member. It can be shown that a kink of less than $^1/_{16}$ inch in the channels of Column No. 1 between adjacent lacing bars might cause a bending moment which would increase the extreme fiber stress in the channel 50 percent. It should also be noted that the column formulae in common use all depend on the assumption that the whole column acts as a unit, i. e. the entire cross section of a column preserves its integrity under stress; in the light of the above tests the truth of this assumption seems somewhat questionable.

The tests to failure showed striking differences between

the behavior of Column No. 1 with its thin parts and the wrought-iron columns with their stockier section. Column

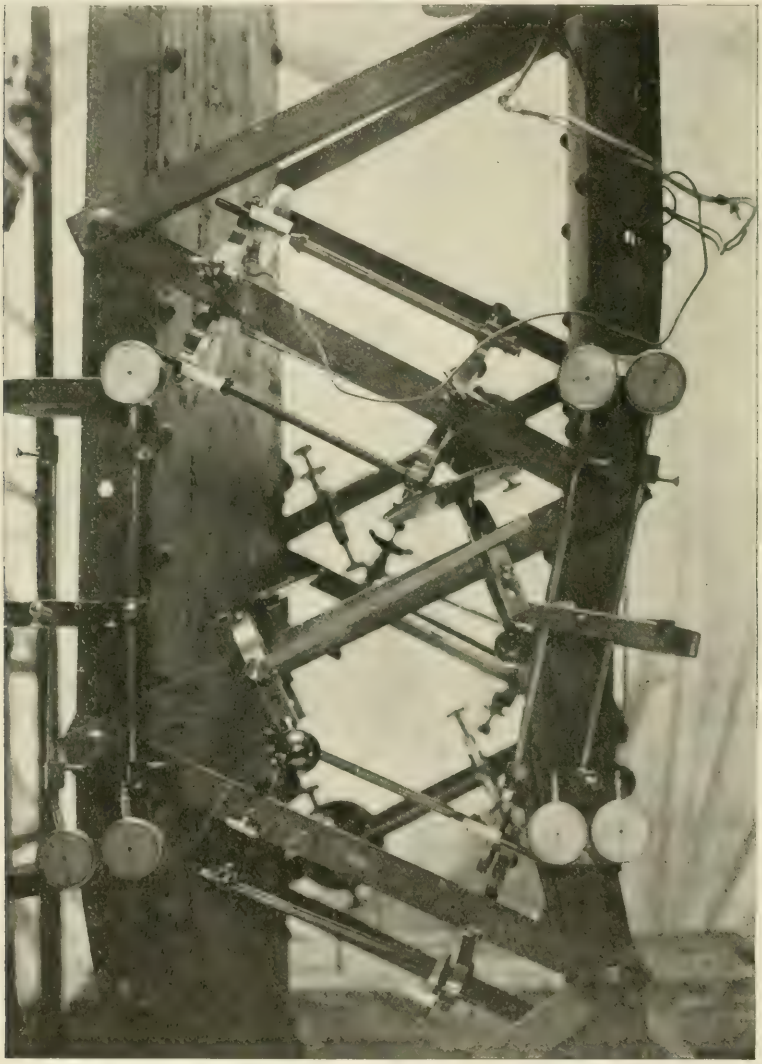


FIG. 3.
FAILURE of COLUMN No. 1

No. 1 was at first fitted with very light lacing bars, and in one test the load was applied with a slight obliquity. Under an

average compressive stress of about 8000 lb. per sq. in. of cross section the column failed suddenly by the buckling of several lacing bars in the upper half of the column. Failure by buckling of lacing bars is a very unusual method of failure of columns, and this test is therefore of unusual interest. The testing machine was stopped before any serious damage was done to the channel members, the light lacing was removed, and heavier lacing riveted in its place. The column was then tested again for stress distribution and finally loaded to failure with a central axial load. Failure occurred at an average compressive stress of about 23,500 lb. per sq. in. of cross section by the sudden "wrinkling" of one flange between adjacent lacing bars at a point one third of the length of the column from the top. At this point of failure previous stress distribution tests had shown the greatest stress observed in the column. Fig. 3 shows the failure. The wrought iron columns all failed by a failure of end details or by a gradual bowing of the columns as a whole. The failure in general took place where the previous stress distribution tests had shown a high stress, though not necessarily where maximum stress had been found. The gradual failure of the stocky wrought-iron columns was in sharp contrast with the sudden failure of the flimsy steel column (No. 1), and the general behavior of the wrought-iron columns seems to show that in a column built up of thick pieces there is a considerable tendency to equalize stress distribution before final failure occurs. Table 3 gives the results of tests to failure.

The function of the lacing bars in a built-up column is to hold the flange members together and to make the column act as a unit. Even if they perform this duty only imperfectly they will be under stress if any bending tendency exists in the column, and the stress on any bar may be either tension or compression. Evidently a lacing bar would be weaker in compression than in tension. A series of tests on the strength of lacing bars in compression was carried on in connection with the tests on columns. The test lacing bars were fastened to special compression blocks in a testing machine by means of bolts in such a way that they received their load in a manner similar to that of lacing bars riveted to the channel members of a column. The test bars acted as long columns eccentrically loaded and failed under light compressive loads.

Fig. 4 shows the results of tests to failure. Length of bar is measured from center to center of rivet holes. It would seem that in a column flat lacing bars in compression are capable of carrying at failure an average stress equal in no case to as much as half the yield point strength of the material of which they are made. The loads carried by lacing bars in actual columns is small, but the ability of the bars to carry load is also small. Bars of channel or angle section seem to be stronger than flat bars.

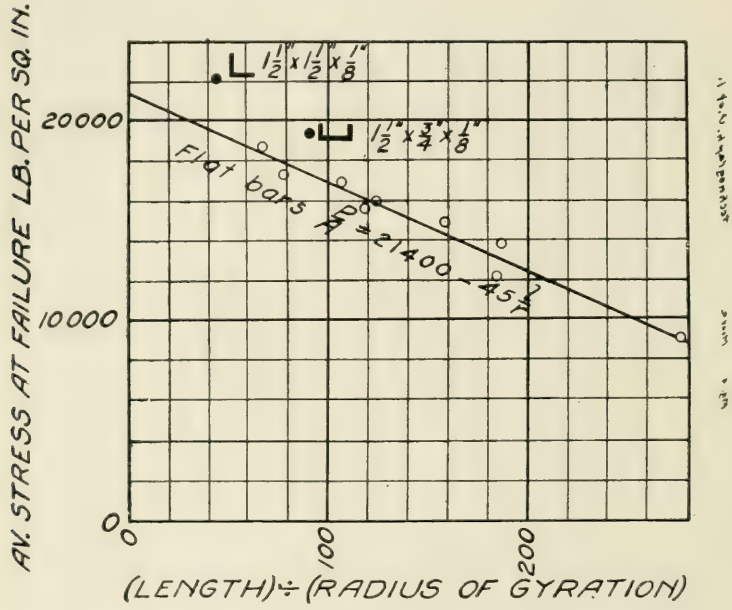


FIG 4
RESULTS OF COMPRESSION TESTS OF LACING BARS.

In the columns tested in the testing machine an attempt was made to find some relation between the compressive load on the column and the load on the lacing bars. As might be expected from the very uneven distribution of longitudinal stress throughout the column, the stress in different bars differed greatly. Table 4 gives the maximum stresses found in the lacing in terms of the compressive load on the column. It will be seen that stresses in the lacing of some of the columns were as great as would be caused by a sidewise shear

of 2.5 or 3 percent of the compressive load, or to put it in another way, there were observed stresses in lacing bars as great as would be caused by a sidewise load at the center of the column equal to 5 or 6 percent of the compressive load on the column.

TABLE 1

Data of Columns

Column Designation	Column No. 1	Wrought Iron Posts		White Heath Bridge	
		No. 2, 3, 4 and 5	Retests* 2a and 4a	Posts U_3L_3 south U_3L_3 north	Upper chord U_3U_4 south
Area column section in square inches	18.76	17.64	17.64	12.02	48.67
Length center to center	21 ft.	15 ft. 10 in.	14 ft. 7 in.	25 ft.	19 ft. 10 in.
End conditions	Pin parallel to lacing	Pin parallel to lacing	Pin parallel to lacing	Lower end pin, upper end riveted	Riveted
$\frac{l}{r}$, axis parallel to lacing	37.8	43.5	40.1	66.1	40.7
$\frac{l}{r}$, axis perpendicular to lacing	37.2	41.2	38.0	41.0	29.6
$\frac{l}{r}$ of each flange member, axis perpendicular to lacing for whole column	593	400	367	416	....
$\frac{l}{r}$ of each flange, axis as before for distance between adjacent lacing rivets	37.7	33.7	33.7	22.2	....?
Lacing bars, dimensions of section in inches	$\left\{\begin{matrix} 1\text{x}1\frac{1}{4}\text{ in} \\ 1\frac{1}{4}\text{x}\frac{7}{16} \end{matrix}\right\}$	$2\frac{1}{2}\text{x}\frac{3}{8}$	$2\frac{1}{2}\text{x}\frac{3}{8}$	$2\frac{1}{4}\text{x}\frac{3}{8}$	$2\frac{1}{4}\text{x}\frac{3}{8}$ on bottom
Kind of lacing	Single	Double	Double	Double riveted at crossing	one cover plate
Angle of lacing bar with axis of column	63° 30′	45°	45°	45°	45° on bottom

*After failure of the ends of columns No. 2 and 4, the damaged ends were cut off, new end plates bolted on, and the columns retested as columns No. 2a and 4a.

TABLE 2

Maximum Observed Fibre Stresses in Flange Members of Columns

Col. No.	Where Tested	Test No.	Features of Lacing	Method of Loading	Percentage of excess of maximum fibre stress over average stress. Highest five values.				
1	Testing Machine	1	$1\frac{1}{4}$ x $\frac{7}{16}$ in. bolted	Central	42	41	39	31	23
1		2	do.	Slightly eccentric	68	64	50	49	35
1		3	do.	do.	50	41	35	32	19
1		4	1 x $\frac{1}{4}$ in. bolted	Central	35	29	28	27	26
1		5	1 x $\frac{1}{4}$ in. riveted	do.	67	55	49	29	27
2		6	$2\frac{1}{2}$ x $\frac{3}{8}$ in. riveted	do.	31	23	23	21	17
3		7	do.	do.	20	17	12	11	9
4		8	do.	do.	41	29	24	22	19
5		9	do.	do.	43	43	38	5	35
4a		10	do.	do.	53	49	42	40	37
2a		11	do.	do.	21	16	13	12	11
2a		12	do.	1 in. obliquity	42	42	24	23	20
2a		13	do.	2 in. obliquity	35	34	22	21	21
U_3L_3	White Heath Bridge	F_1	$2\frac{1}{4}$ x $\frac{3}{8}$ in. riveted	in service	73	63	60	57	47
U_3L_3		F_2	do.	do.	64	48	41	31	31
U_3U_4		F_3	One cover plate	do.	20	19	17	17	17

TABLE 3

Result of Tests to Failure

Column No.	1	1	2	3	4	5	2a	4a
Test Number	X	17	6	7	8	9	13	10
Material	Steel	Steel	W. I.	W. I.	W. I.	W. I.	W. I.	W. I.
Method of Loading	Very slight obliquity	Central	Central	Central	Central	Central	2 inch obliquity	Central
Load at failure, lb	150 000	440 000	466 000	480 000	452 000	492 000	475 000	475 000
Average stress at failure, lb. per sq. in	8 060	23 450	26 400	27 200	25 700	27 900	26 900	26 900
Average Stress at Failure in Tests of Short Pieces of flange members, lb. per sq. in	.....	.....	36 800	36 800	36 800	36 800	36 800	36 809
Percentage of Excess of Ultimate Strength of Short Pieces over Column Strength	.....	.....	39.5	35.5	43.5	32.0	37.0	37.0
Load at first Sign of Yielding, lb	150 000	225 100	317 000	264 000	256 000	264 000	.....	.....
Average Stress at first Sign of Yielding, lb. per sq. in	8 060	12 000	18 000	15 000	14 500	15 000	.....	.....
Method of Failure and Remarks	Very sudden buckling at lacing bars in upper half	Sudden buckling of flange between adjacent lacing bars	End failed	End failed	End failed	Bowed at middle in plane perpendicular to lacing	Buckled near bottom in plane parallel to lacing	Bowed at middle in plane perpendicular to lacing

TABLE 4

MAXIMUM OBSERVED AVERAGE STRESS IN LACING BARS

Column No.	1	1	1	2a	2a	2a
Test No.	5	14	15	11	12	13
Method of Loading	Central	Central	4 in. obliquity	Central	1 in. obliquity	2 in. obliquity
Total load	187 600	187 600	187 600	176 400	176 400	176 400
Lacing	Single $1 \times \frac{1}{4}$ in.	Single $1\frac{1}{4} \times \frac{7}{16}$"	Single $1\frac{1}{4} \times \frac{7}{16}$"	Double $2\frac{1}{2} \times \frac{3}{8}$"	Double $2\frac{1}{2} \times \frac{3}{8}$"	Double $2\frac{1}{2} \times \frac{3}{8}$ in.
Maximum observed average stress in lacing bars, lb. per sq. in.	8 200	3 000	4 900	3 900	4 350	4 350
Corresponding total stress, lb	2 000	1 600	2 700	3 700	4 100	4 100
Corresponding transverse shear in column, lb	3 700	2 900	4 800	5 200	5 800	5 800
Shear due to known obliquity of load, lb	0	0	3 000	0	1 000	2 000
Transverse shear in column due to nominal central load, lb	3 700	2 900	1 800	5 200	4 800	3 800
Ratio of shear to compression load	0.020	0.016	0.009	0.029	0.027	0.021
The highest values of ratio of shear to compressive load	0.009	0.010	0.009	0.024	0.019	0.016
	0.008	0.010	0.007	0.023	0.018	0.014
	0.008	0.009	0.006	0.010	0.018	0.014
	0.007	0.009	0.006	0.008	0.018	0.011

WHAT'S WHAT IN ARCHITECTURE.

LEON F. URBAIN, Arch. '10.

It is true that some form of architecture has always existed—"Architecture is the printing press of all ages and gives a history of the state of society in which it was born." Prehistoric man took a great pride in shaping his "cave" home, and building his branch shelter, imitating the lairs of beasts and the nests of birds.

With the flight of time, prehistoric architecture became a tradition, and we find our first semblance of the column, and the lintel in Egypt, about the year 4700 B. C. Here we find tombs enriched with carvings and color, the pyramids and obelisks, a wonderful variety of sculpture and ornament, a real beginning of true architecture.

Crossing to Assyria we note the Egyptian influence in the Babylonian temples, and going farther into Persia, we see the new influence in the architecture of its royal palaces, all finally culminating in the graceful and lasting Grecian models. Here the foundation for all future progression was laid firmly and broadly, so that a wonderful variety of styles has sprung up and flourished, during the succeeding centuries, from this base.

The Romans took a modified Greek, mingled with it some Etrusian, added the arch, the dome, introduced the superimposed orders, and a profusion of ornament, finally giving us the Roman Classic, which applied itself readily to a very wide range of buildings for a wide range of uses.

Meanwhile, Byzans was at work. Its new ideas; its new capitals, and shafts, its low, bold relief, and mosaics were brought to Rome, and Italy and a mingling became apparent in the new style which we call Romanesque.

New factors were ever arising in these centuries of energy and change. Variety was at a premium. The dawn of a new architecture, different from any that had ever been seen, was at hand, and emerged spontaneously in France, early in the twelfth century.

"Graceful, grotesque, with ever new surprises

of hazardous caprice sure to please,
Heavy as nightmare, airy, light as fern.
Imaginations very self in stone."

But even these lofty naves and transepts, these "shell like spires" and towers of Gothic architecture, these buttresses and pinacles and beautiful tracery windows, these rose-like perfections in stone were to hold the stage for only a few centuries, only until that a cry of progress and variation would again call the architects to renewed attention.

Materials are signals of attention, which may be either commendation or warning. The good that architectural elements possess, lives long after their creators have been forgotten and good inevitably claims revival. Thus the Renaissance claims a revival of the classic adopted to its new condition. We find new proportions and details of course, but the best renaissance retains the smile of Greecian and Roman classical styles.

The Renaissance may properly be called, a renaissance of light and shade, succeeding the Gothic which was more "pure form."

The Italian villas, with their beautiful gardens, fountains and terraces, now began to introduce a touch of real life, with its ease and pleasure.

"A fuller light illumined all
A breeze then all the garden swept."

The architect now assumed a personality and a prominence never before awarded to him. He became a recognized potent factor in the wheel of progress, filling a position, indispensible to the demands of increased commercialism and competition.

Architecture is not merely European, as we have viewed it up to this time, but cosmopolitan.—We have said nothing of the Oriental style:—

"See what a love shell,
Small and pure as a pearl.
Frail, but a work divine.
Made so fairly well,
With delicate spire and wall,
How exquisitely minute
A miracle of design."

Each of these great styles had its period, and each period its types, which were fitted to the country fostering them.

So much has been accomplished in these past centuries; such a high standard has been set, and such a profusion of ideas and details, in every phase of architecture has "worked out" that we often hear the statement—"There is nothing new in architectural fundamentals. All that remains in originality, is simply new combinations."

To a beginner this seems on the one hand inspiring, because of the wide field that he is at liberty to choose from, on the other, daunting, because of the apparent difficulty in equaling the magnificent examples already erected; and because of the fact that most ambition desires to do something original, which older minds declare next to impossible in architecture. Be that as it may, to the writer, architecture is yet a new field, despite its years, and still brim full of new ideas, despite the fact that it has been drawn upon, since the beginning of man.

The training of the architect is a very important subject. Men were trained in those years of monuments by the long, hard road of experience. They had no books but studied in the shop, as it were, where the real achitecture was made in form, instead of in words.

While we look back and survey the architecture of these men, for the last 6000 years, and judge it marvelous, who will venture to say how marvelous, how many times more splendid and igenious, we would judge the architecture of the next 6000 years, if the future was as open as the past.

While we are not especially interested in 5000 A. D. we must build to suit the present. To design and build satisfactorily we must be prepared and to be prepared we must have those inherent prerequisites and the best instruction obtainable.

The Architectural centre of the world became concentrated in France in the time of Louis XIV. At that time a school was founded that became the centre of architectural instruction and influence. By years of study, a method of teaching this profession was perfected that has bowed to no system so far produced. Today L'école de Beaux Arts is still the most influential architectural centre that we have, and

every year many students avail themselves of the opportunity of studying here.

Some schools in the United States have adopted this system of instruction, to a great extent. Optimists say, that the time is not far distant when the American school will equal L'école de Beaux Arts in efficient instruction and surpass it for American needs. Some claim that distinction now, but conservatism tends to refute.

There are now three distinct methods of teaching architecture in America.

1. The draughting room and Atelier (The office).
2. The method of the Western and Middle Western schools.
3. The Beaux Art-Method.

For a long time the draughting room, and the apprenticeship system was the only one available. The students learned from one master, getting all his methods and secrets. He was a capable man when he got through and could design architecture provided his master was a good architect. But he had one style and one way of doing everything except the little initiative which might remain after such a grind. Again he knew very little of other arts and sciences and architecture became a trade for a trade's sake.

Secondly, most of the Western schools have what we term a four year course. A student enters as a freshman, upon a course of study, prescribed in detail, as to subject, quantity, time and year. The quality in such a course, is maintained by the *minimum mark of* 70%, all students falling below this mark, being required to take the subject over again. A poor student, falling below the mark, is further loaded with this *"back-work"* and this has often sufficed to quench what enthusiasm and ambition there was remaining. The passing mark of 70% is too often the only requirement which must be met, and it is a deadening influence. It brings down the average of the work to this dividing line and contains no element which would foster better work. (Contrast this, with the system described in the third method).

Where ever possible, more than one man should be employed to teach design. Where such is not the case the student will necessarily be "subject to the domination and

tastes" of one man. This is the same difficulty that we noticed in the apprenticeship method and while not so glaring, it is never-the-less in existence and in operation.

Thirdly.—The Beaux Art system. Here the course is no longer held within the boundary lines of four years, but each student is placed upon his merits. There is no passing mark of 70%. The graduation requirements are stated in points, which are proportional somewhat to the number of hours required by the course—each student takes what he can, regarding the prerequisites of course, and advances as fast as he can. A well prepared student can finish the course in three years while another will take five years.

The Atelier is joined directly to the course, being under the direction of practicing architects in conjunction with the professors, who act as a jury to judge all designs. The jury, whose personnel changes, awards three grades, "passes," "mentions" and "special mentions" counting each for a special number of "points." Promotion from grade to grade depends on the number of points. This puts the premium on quality rather than quantity. Three (3) mentions count as four (4) passes and three (3) special mentions as five (5) passes. There is no back work in this system. If a student fails to make the lowest mark, "pass," he is stimulated to do better work on the next problem and get "special mention" so as to make up the last point. Each student advances as fast as his talents and ambitions permit. This system induces a new freedom, a good will and an incentive to do good work.

Furthermore, having men who are doing real architecture associated with the Atelier in this way, inspires confidence in the students, and enables them to keep up with all modern ways and changes of design and building.

In general, a system of instruction should at all times give as many electives as possible. At all times the smaller university community and the smaller field of knowledge promoted unity and fixed the standard of the university. But in recent years there has been such a diversity in the two lines, that unity is no longer absolutely possible. The various fields have been subdivided because of the increased knowledge and the dawn of specialists has arrived, consequently electives are necessary.

At the same time the fact must always remain, that, a university is not supposed to turn out men who can superintend a building as well as the man of experience and ability, nor is it supposed to turn out inefficient specialists, but men who are well rounded, who have built a foundation upon which experience is to build, in its turn, with safety. The university must give to a student, first of all, a scholarly attitude of mind.

A NEW CHARACTERISTIC EQUATION OF SUPERHEATED STEAM.

P. F. POPP, M. E., '11.

Many different equations have been proposed to represent the properties of superheated steam. The rational equation proposed by Van der Waals on the basis of the kinetic theory of gases has the general form

$$p=\frac{BT}{V-b}-\frac{C}{V^2}. \tag{1}$$

The modified form of this equation as given by Clausius is

$$p=\frac{BT}{V-b}-\frac{f(t)}{(V+c)^2}. \tag{2}$$

While these equations give good results for some fluids they cannot be made to hold accurately for superheated steam. Zeuner's empirical equation

$$pV=BT-Cp^n \tag{3}$$

has been much used, but as has been shown by Linde, has a form fundamentally incorrect. From certain assumptions Callender has deduced the equation

$$V-b=\frac{BT}{p}-c_0\left(\frac{273}{T}\right)^{3.5} \tag{4}$$

which represents the experimental results of Knoblauch, Linde and Klebe with fair accuracy up to 160° C. At higher temperatures the volumes given by formula (4) are somewhat larger than those determined by experiment.

A characteristic equation proposed by Linde and generally accepted as representing most accurately the properties of superheated steam as determined at the Munich Laboratory has the form

$$pV=BT-p\,(1+ap)\left[C\left(\frac{373}{T}\right)^n-D\right] \tag{5}$$

With pressures in kilograms per square meter the constants have the following values

$a = 0.000\,002$	$C = 0.031$	$n = 3$
$B = 47.10$	$D = 0.0052$	

In the discussion of this equation Linde calls attention to the factor.

$$C\left(\frac{373}{T}\right)^n - D$$

which changes sign at a temperature of about 402°C. At higher temperatures the mixture becomes a more than perfect gas ("ubervollkommenes" Gas)* a condition not in accord with physical facts. Linde suggests that this difficulty may be overcome by giving the exponent n a fractional value .

A recent investigation by Prof. G. A. Goodenough shows that a modified form of Linde's equation represents equally well the experiments of Knoblauch, Linde, and Klebe. This new characteristic equation has the form

$$V = \frac{BT}{p} - (1 + ap)\frac{m}{T^n} \qquad (6)$$

It will be seen that the constant D of Linde's equation does not appear in this equation. It was found that by taking $n = 3.5$ the constant D could be dropped without effecting the accuracy. The resulting equation has therefore a simpler form, which is of decided advantage in further analytic investigations, and furthermore it lends itself more readily to logarithmic computation notwithstanding the fractional value of n. Slight changes were made also in constants a and B for reasons connected with another investigation. The values finally adopted are:

$B = 47.06$ $a = 0.000\,001$
$\log m = 7.41320$ $n = 3.5$

For English units with pressure in pounds per square inch the following are the constants:

$a = 0.0007$ $n = 3.5$
$B = 0.5956$ $\log m = 9.50308$

The values of V given by the modified equation (6) agree very well with those given by the Linde formula taken directly from the recent tables of Marks and Davis, and furthermore these values represent the experimental results of Knoblauch, Linde and Klebe at least as well as the values obtained from formula (5). Table I shows a comparison of values of V in the superheated region as computed from the two formulae. An inspection of the results shows that the specific volumes

*"Mitteilunge über Forschungsarbeiten" Heft 21, p. 68.

TABLE I

Specific Volumes Cubic Feet Per Pound

Pressure Pounds per Square Inch p.	Value of V Saturation		50° Superheat		100° Superheat		200° Superheat		300° Superheat		400 Superheat	
	By Formula (6)	Marks & Davis	By Formula (6)	Marks & Davis	By Formula (6)	Marks & Davis	By Formula (6)	Marks & Davis	By Formula (6)	Marks & Davis	By Formula (6)	Marks & Davis
2	173.76	173.5	188.83	189.2	204.17	204.2	233.76	234.20	263.65	264.1	293.45	293.90
5	73.55	73.33	79.62	79.70	85.67	85.7	97.70	97.80	109.66	109.8	121.65	121.80
10	38.43	38.38	41.51	41.50	44.56	44.60	50.63	50.7	56.63	56.70	62.62	62.70
15	26.30	26.27	28.40	28.40	30.43	30.46	34.49	34.53	38.51	38.58	42.51	42.59
20	20.10	20.08	21.66	21.69	23.21	23.25	26.27	26.33	29.30	29.37	32.31	32.39
30	13.75	13.74	14.82	14.83	15.86	15.89	17.92	17.97	19.95	20.00	21.96	22.03
50	8.52	8.51	9.18	9.19	9.82	9.84	11.08	11.11	12.31	12.38	13.52	13.58
70	6.21	6.20	6.69	6.71	7.16	7.18	8.07	8.11	8.95	9.01	9.83	9.89
100	4.44	4.429	4.79	4.79	5.13	5.14	5.78	5.80	6.39	6.44	7.01	7.07
150	3.02	3.012	3.27	3.27	3.50	3.51	3.94	3.92	4.36	4.41	4.80	4.84
200	2.29	2.290	2.48	2.49	2.66	2.68	3.01	3.04	3.33	3.38	3.64	3.71
300	1.55	1.551	1.68	1.69	1.81	1.83	2 04	2.09	2.27	2.33	2.48	2.55

calculated by the modified formula agree well under all conditions with those of Marks and Davis. Columns 2 and 3 of Table I give the values of V at the saturation limit. The values in column 3 are those given by Marks and Davis as calculated from the latent heat r and derivative $\frac{d\,p}{d\,t}$

The following table gives values of V at saturation calculated from (6), the experimental results of Knoblauch, Linde, and Klebe the values computed from (5) and finally those calculated by Henning.

TABLE II

SPECIFIC VOLUMES V AT SATURATION

Degrees C. t	By Formula (6)	Experiments at Munich Laboratory	By Formula (5)	Calculated by Henning
100	1.673	1.674	1.674	1.673
120	0.8913	0.8922	0.8915	0.8912
140	0.5081	0.5091	0.5083	0.5078
160	0.3069	0.3073	0.3070	0.3071
180	0.1944	0.1943	0.1943	0.1947

Henning* made his calculations on the basis of his recently determined values of the latent heat and Holborn and Henning's very accurate values of $\frac{d\,p}{d\,t}$. The remarkably close agreement of the values calculated by Henning and those determined directly by Knoblauch, Linde, and Klebe is convincing evidence of the extreme accuracy of both sets of experiments. The values obtained by (6) give slightly better results than Linde's formula and agree almost exactly with Henning's values. Therefore equation (6) represents with sufficient accuracy the values of V at the saturation limit.

A very convenient method for comparing the calculated values of V with the experimental results is that used by Linde and shown in Fig. 1. For a given temperature the prod-

*F. Henning, Annalen der Physik Bd 29, p. 464.

ucts (p V) are plotted as ordinates and pressures (p) in kilograms per square meter as abscissae. Inspecton of (6) shows that with T constant, the curve giving the relation between pV and p is a parabola. Similarly for Linde's equation (5). Callender's equation, however, gives the isothermals as straight lines. The points of Fig. 1 represent the experiments of Knoblauch, Linde, and Klebe, and close inspection shows that they lie not on straight lines but on very flat curves. The curves of Fig. 1 are the isothermals calculated from (6) corresponding to the experiments just cited. The agreement between the curves and the experimental points is satisfactory, and the new formula may therefore be considered as capable of giving as accurate results as the Linde formula. Its advantage over the Linde formula lies in the greater ease of computation, due to the elimination of the constant D.

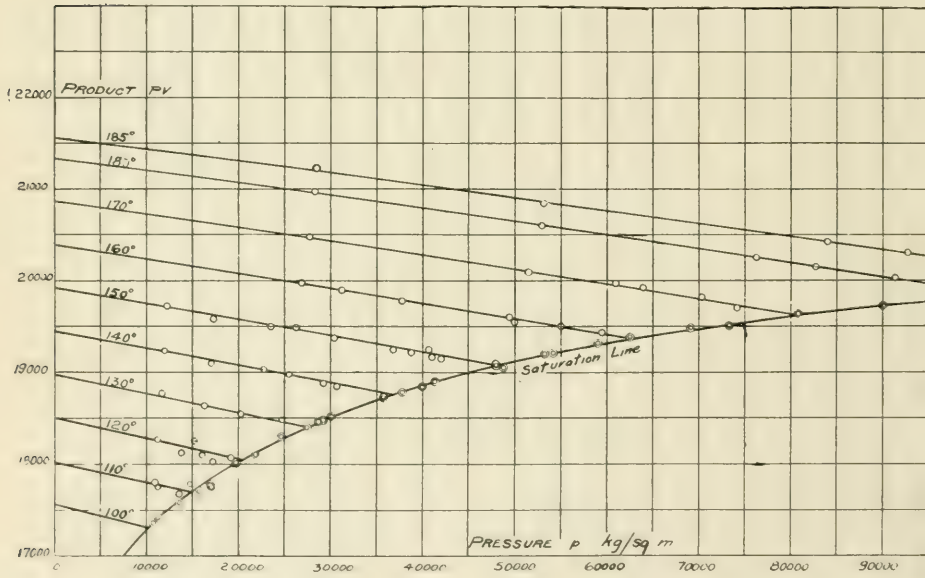


FIG 1

THE NEW UNIVERSITY POWER PLANT.

JAMES M. WHITE, B. S.
Supervising Architect.

The writer has in his files an autographic report made to the Board of Trustees, under date of September 11, 1893, by Professor L. P. Breckenridge, recommending the improvements he considered necessary to furnish the University with adequate heat, light and power facilities. At that time (according to the report) there was a total of 46,000 square feet of heating surface in our buildings; and no tunnels had been constructed.

In accordance with his recommendations, the present power house was designed and erected, and a system of tunnels constructed, leading to all of the buildings then existing; which established a policy that has been consistently followed up to the present time.

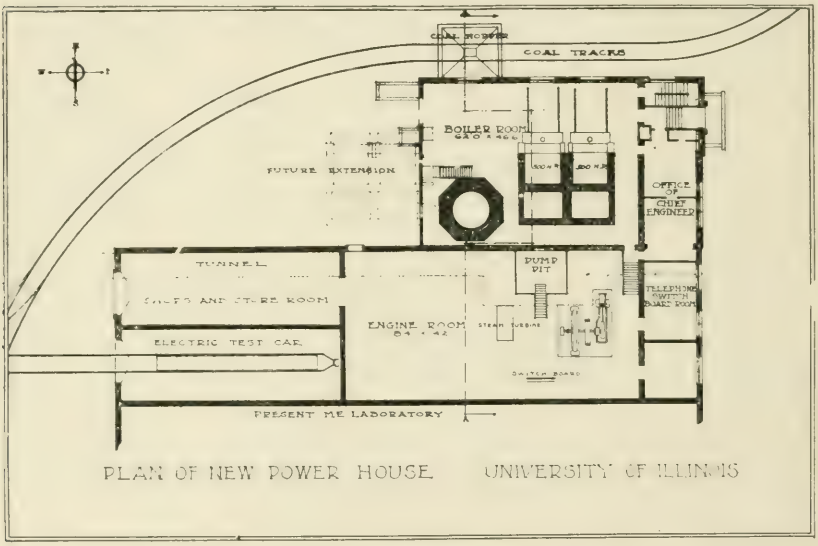
We have now the equivalent of 200,000 feet of direct radiating surface in our buildings; and the demand for power and light has increased proportionately. The equipment of the boiler house has been increased to 1800 H. P. of water-tube boilers, in units of 225 and 250 H. P.; and, though the chimney capacity does not exceed 1600 H. P., all of the buildings have been successfully heated during the past winter, but the equipment was forced to the limit and there is no floor space for additional boilers, and insufficient height for larger units.

As there seemed to be no question about the advisability of our changing our policy in regard to size of boilers and adopting 500 H. P. units for our future extensions; and, as a proper setting of these units in order to provide adequate coal and ash handling machinery would require a basement, it was impracticable to make the new boiler house an extension of the old one, so it was decided to construct an entirely new building, extending at right angles to the present one and paralleling the Interurban track, over which practically all of our coal is now received.

The plan and section of the new building need but little explanation: The chimney is to be 10 feet in diameter at the

top and 175 feet high above the boiler room floor, which gives it a rating of about 3500 H. P., although it is intended to carry only two batteries of 1000 H. P. each. The usual rating of chimneys is on the basis of a good grade of fuel and the increased capacity is provided to allow for running both batteries to at least 50% overload, with the $1^1/_4$" screenings which we use. The chimney will be built by the Alphons Custodis Chimney Construction Co. of Chicago.

$75,000.00 will be spent upon the building and equipment, but this will not permit the installation at this time of the coal and ash handling machinery. The boilers which



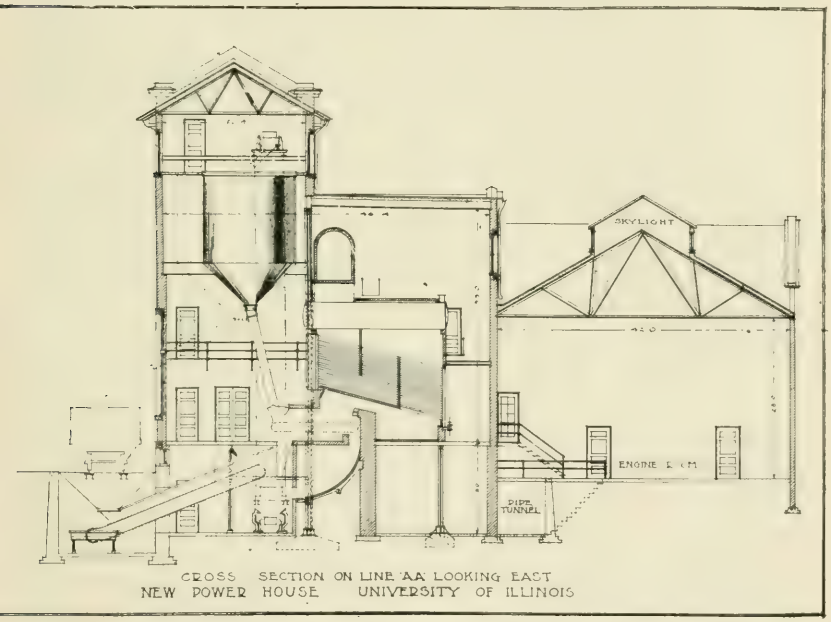
PLAN OF NEW POWER HOUSE. UNIVERSITY OF ILLINOIS

have been contracted for are Babcock and Wilcox 500 H. P. boilers, with cast iron headers, and they will be set with the Green Engineering Company's chain grates.

The coal will be unloaded from the cars into a hopper, from which it will be taken by a pan conveyer to the bucket conveyer; and a crusher will be installed for use when necessary. The bucket conveyer will also handle the ashes and the fine coal drippings. Hopper-bottom, cylindrical steel bunkers have been adopted, because there is so much danger from spontaneous combustion with the low grade of fuel used, that it was felt essential to have the bunkers so constructed that

the coal would be constantly moving. The ash bunker will be situated in front of the chimney. It will probably be necessary to provide a cross conveyor for emptying the ash bin, but the best type for this purpose has not been decided upon.

The plan shows that the boiler house can be extended to the west, where there is ample room for all the extension that will be necessary to provide heat and power for the University for at least twenty-five years, by which time some other location may be more desirable and boiler house practice will have made further advances, with which we must keep pace.



CROSS SECTION ON LINE 'AA' LOOKING EAST
NEW POWER HOUSE UNIVERSITY OF ILLINOIS

In addition to being mechanically efficient, it is important to have our equipment thoroughly up to date so that it will be a creditable laboratory for our engineering students. This last consideration justifies us in installing coal and ash handling equipment which would not be justifiable in so small a plant on the score of economy in operation.

The chief service required of the power house is that of heating, for the lighting and power load is not likely to be more than a quarter of the heating load. The present engine

room equipment consists of a 120, and a 75 KW, 440 volt, 2 phase, 60 cycle generator, an 85 KW, 220 volt, 3 wire, direct current generator, and a 25 light arc machine. This equipment has been very much overloaded to give us the inadequate lighting and power service, with which we have been forced to get along. Some relief has been secured through the equipment of the electrical engineering laboratory, but the maximum alternating current capacity is now only 230 KW.

Some of the present equipment will be transferred to the new engine room; and, in addition, a simple Ball engine, direct-connected to an Allis-Chalmers Co. 250 KW generator, and a 125 KW. steam turbine, which is a portion of the equipment of the electrical laboratory, will be installed. A simple engine was chosen because the exhaust steam is used for heating, and the engine therefore becomes merely a reducing pressure valve for the heating system.

The building will be completed by June 1, and the equipment installed soon after. It would be impossible to build a larger boilerhouse at this time without cutting out the coaling switch for the old boiler house, which of course must continue in service for five or six years, until an addition can be built to the new boiler house and another battery of boilers be set.

The new mechanical equipment was decided upon by Mr. W. L. Abbott, President of the Board of Trustees, and Dean W. F. M. Goss of the College of Engineering. The details of piping and wiring, together with the selection of pumps, feed water heaters, etc., has been entrusted to Mr. W. H. Zimmerman, '96, who now has offices as Consulting Engineer in the First National Bank Building, Chicago. The plans for the building were prepared by Mr. W. C. Zimmerman, the State Architect; and the general contract has been awarded to Mr. E. C. English of the class of 1902.

THIRD ANNUAL ELECTRICAL SHOW.

HOWELL H. REEVES, E. E. '10.

The Third Annual Electrical Show of the University of Illinois was held in the Electrical building on the evenings of February 10, 11, 12, 1910. This show was given by the students in Electrical Engineering for the following reasons. They wished to gain some practical experience in electrical work; they desired that those who could avail themselves of the opportunity should have the chance to see the recent applications of electricity to the fulfillment of human needs, and they also hoped to demonstrate to the people of Illinois that a university training was capable of results.

The organization was slightly different from that of the preceding shows. The work was divided between three departments, one having charge of the engineering, one of the advertising, and the third of the finances. There was one man with one or two assistants at the head of each of these departments. Above the three departmental heads was a general manager, who as his title indicates had general charge of the whole show. The personnel of the management was as follows:

W. J. Putnam	General Manager
H. M. Turner	Engineer
C. H. Reeder	Advertising Manager
H. H. Reeves	Business Manager
J. F. Chinlund	Treasurer
E. D. Doyle	Assistant Advertising Manager
W. E. East	Assistant Engineer
H. A. Moore	Assistant Engineer

The engineering department had charge of the exhibits. These fall naturally into three divisions, heating and cooking, lighting, and the transmission of intelligence. Much of the apparatus in the first groupe was supplied by the General Electric and Westinghouse Companies. In the electric kitchen on the third floor were chafing dishes, toasters, corn poppers, hot water cups, cooking and baking outfits, tea kettles, coffee percolaters, electric stoves and numerous other house-

hold appliances. The kitchen was in charge of a number of co-eds from the Household Science department and they were kept busy serving the great throng of visitors with toast, coffee and fudge.

The lighting exhibit was very instructive to everyone. Electrical power has perhaps no more important application than that to illumination. There is, however, a great diversity in the forms of electric lamps owing to the recent development of the Tantalum, Nernst and Tungsten incandescent lamps, the vapor lamps, and the luminous flaming arc lights. These lamps have different colors, different costs, and different operating characteristics and the problem of choosing the proper lamp for the place to be illuminated is one incapable of solution by the layman at a moment's notice. A whole room at the show was devoted to this subject, the lamps being shown in operation and their various characteristics were explained by those in charge.

Among the exhibits dealing with the transmission of intelligence were the magneto, central energy, automatic, and wireless telephone system, the speaking arc and the wireless telegraph. Two complete stations of the wireless telephone were displayed by Mr. Maddox of Bateman, Garrison, Maddox Co. Much amusement was furnished by the speaking arc which seemed to have almost human intelligence. It would talk to the people in the room, calling them by name and referring to them in unmistakable terms.

There were many other exhibits not falling within the three general divisions. Some of these were instructive, others simply amusing. Among the former were the vacuum cleaners, lifting magnets, monorail, electric meters, Thordarson transformer, and the measurement of human resistance. The ultra-violet rays and corona effects of high voltages were also of great interest. One of the most popular booths in the show was the Nursery. Here it was shown how electricity could be used to light the fire in the morning and wake the sleeper only after the house had become warm. The baby jumper, and baby spanker also attracted a large amount of attention.

The planning, installing and operation of these exhibts called for the combined efforts of the majority of the electrical engineering students and these efforts were harmonized with

such a lack of friction and such a spirit of good will as to call forth the praise of all. The most notable instance of this was on the last night of the show after the visitors had gone. The laboratory was cleaned of booths and decorations and put in shape for class work within a very few hours by the many willing hands that had already worked hard and long.

It seemed more appropriate to do most of the advertising for the show by electrical means and consequently the advertising department concentrated most of its efforts in the two sky rocket signs, one of which was suspended from the roof of the Flatiron building in Urbana and the other in Champaign. The tails of these rockets were fifty feet long and the burst of colored streamers and "E. E. Show" at the end made an attractive and novel advertisement. The lighting of the library tower with flaming arcs and the search lights on the Main Hall tower helped to arouse interest.

So far as the students are concerned the results of the show are most encouraging. It gave them an opportunity to accomplish things and develop in them a feeling of responsibility and of self reliance. It has drawn the electrical engineers together and developed a feeling of pride in the department and of loyalty to each other as no other student enterprise has done. In no other way could the feeling of good fellowship and the appreciation of the common aims of both have been developed in faculty and students.

THE MINE RESCUE STATION.

ROBERT Y. WILLIAMS, A. B., E. M.

A summary of the work of the Mine Rescue Station at the University of Illinois shows certain progress during its first year's existence. Many interested visitors have studied the equipment and methods of modern mine rescue practice as demonstrated at this station; and about 200 mining men have donned the helmets and entered the poisonous sulphur atmosphere of the "smoke room" to test for themselves the efficiency of these breathing appliances. Despite this favorable report, those in charge of the station regret that more miners have not visited the station for a thorough training continuing over a period of a week or ten days. The greater portion of the visitors have been unable to remain longer than a single day, and their first hand acquaintance with the various machinery has been therefore somewhat limited.

When this Rescue Station was formally opened in March 1909, under the combined efforts of the United States Geological Survey, the State Geological Survey, and the University of Illinois, the purpose of its establishment was explained as being primarily educational. The station was designed to demonstrate the modern mine rescue tactics to the mine inspectors, operators and miners, and the equipment was provided with a view to supplying the appliances necessary to allow the engineers in charge of the station to enter and examine mines in order to determine the causes and consequnces of mine fires and explosions. It was further explained at the dedication of the station a year ago that in the event of a mine fire or explosion occurring prior to the establishment of Joint Rescue Stations by the operators of the state, the equipment of this station would be hurried to the scene of the disaster and all possible assistance given in the work of rescue. During the past twelve months, we have been called into the field on the occasion of 2 explosions, 7 fires, 4 mine examinations with the aid of the helmets, and 2 conference demonstrations.

This campaign of education on the part of the Urbana Rescue Station has obtained important results aside from the

material assistance given in the work of rescue at the disasters visited. Today there are three private rescue stations in Illinois, installed by mine owners to protect the lives of the miners under their charge: and on February 17th the Legislature enacted a law establishing three state rescue stations and providing an appropriation large enough to equip each station with all the necessary appliances for making safe and rapid the work of rescue following a mine disaster. This action makes Illinois the first state in the Union to recognize the value of modern mine rescue tactics and to adopt these methods as a safeguard to the lives of the 70,000 citizens who are engaged in the Illinois Coal Mining Industry.

NEW RAILWAY MECHANICAL EQUIPMENT.

During the present year the Railway Engineering Department has made the following important addition to its mechanical equipment.

A Drop Test Machine built according to the specifications of both the Master Car Builder's Association and the American Maintenance of Way Association. It is similar to the few existing machines of the same name with the exception that it embodies one or two improvements over the older ones, and is very complete in the matter of fixtures for special work. By means of this machine, various railroad materials, such as axles, draft gears, couplers and rails are tested for conformity with specifications by subjecting them to the impact of a 1640 lb. or of a 2000 lb. weight, falling through a distance of from three to fifty feet, as the specifications or the resistance of the material being tested may require.

A Brake Shoe Testing Machine built according to the requirements of the Master Car Builder's Association. This machine was designed in detail by the Department in order that certain improvements might be embodied, such as provision for heavy journal bearing and lubrication tests. It is used in making various tests bearing upon the coefficient of friction or retarding effect of various designs and materials in use, per work done. This is a matter which, in view of the annual expenditure by the railroads of the country of about $7,000,000.00 for shoes, has for many years occupied the close attention of the Master Car Builder's Association.

A Suspended Locomotive Counterbalancing Model, by Professor Dalby, so arranged that various methods of counterbalancing either two or four cylinder stationary engines or locomotives may be investigated, and the results compared with the results of mathematical analysis. The model is so designed that all crank angles as well as all reciprocating and revolving weights may be changed at will.

A set of four Maihah-Parrish Continuous Indicators with electro-magnetic attachments for operating the pencil motion and advancing the paper and device for opening and closing the cocks, permitting the attachment of the indicators

in the most advantageous positions as regards short pipe connections and regardless of bringing them within reach of the operator. Indicator cards may thus be taken from the dynamometer car with corresponding record on the chart opposite the various records such as speed and draw bar pull. The long pipe connections usually employed may be done away with and some interesting results from engines in actual road service are looked for.

A Westinghouse Air Brake equipment designed primarily for instructional purposes, and arranged in series with the New York equipment already belonging to the Department. In addition to covering the usual engine, passenger and freight equipment with which every one is familiar, the equipment includes the following features:

Combined automatic and straight air
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Sectional models of all complicated parts are included. These are connected when possible in tandem with operating parts in such a manner that the operations of all internal parts are visible. In erecting the apparatus, liberal use was made of by-passes, cocks and gauges for illustrating defects in the usual manner. In addition, provision is made for showing the building up and down of various pressures in serial action in order to demonstrate to the student as clearly as possible the points which are now occupying the attention of railroad clubs and of air brake instructors in connection with the handling of long heavy trains in severe service.

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NEW PUBLICATIONS.

"Designing and Detailing of Simple Steel Structures" is discussed by Clyde T. Morris in an interesting book just from the press. It contains a collection of important items which are applicable to simple structures collected from the many larger works on structural steel design. The author assumes that the student has a fair knowledge of stresses and does not take up the methods of calculating these. The same notations are used thruout the book, making the equations as simple as possible.

Among the items taken up are the following: Riveting; Designing and Estimating; Manufacture and Erection; Roofs; Plate Girder Bridges; Pin connected Bridges.

The book has 192 pages, illustrated by diagrams when needed, and fully indexed. The price is $2.25.

The "Inspectors' Hand Book of Reinforced Concrete," by Walter F. Ballinger and Emile G. Perrot, recently published by the Engineering News Publishing Company of New York, contains sixty-three pages of valuable information to engineers. The subject is taken up in three divisions:

(1) "Forms of Falsework" in which the various forms are discussed, giving methods of putting up and knocking down.

(2) "Reinforcement." Different methods are described, giving advantages and disadvantages.

(3) "Concrete." Different ingredients, proportion, method of mixing, etc.

In addition to the above, there is added an appendix containing formulae and tables to be used in calculating the strength of reinforced concrete. The price of this book is $1.00.

"Bridge and Structural Design," by W. Chase Thomson, published by the Engineering News Publishing Company has just come from the press. This book contains 187 pages, and takes up the general principles of design, illustrating by numerous examples. The analytical and graphical methods are both used in determining the stresses. The theory involved

is expressed in a simple way, and for those whom the book is intended, students and draughtsmen, it should be easily understood. Price $2.00.

"Tables and Diagrams for obtaining the Resisting Moments of Eccentric Rivited Connections," by E. A. Rexford, has just been received from the press. This book is composed entirely of tables and diagrams, with a few explanatory notes, the purpose of which is to facilitate the operations of obtaining the resisting moments of eccentric riveted connections. It is intended for use in designing connections to columns where eccentric loads are involved. Different problems may easily be applied to the diagrams and the resulting moments obtained. The book contains 29 plates, 4 diagrams to the plate, and sells for one dollar.

"A History of the Logarithmic Slide Rule and Allied Instruments," by Florian Cajori, Ph. D., has recently been issued by the Engineering News Publishing Company. The history of the slide rule is taken up very completely, giving a description of the various kinds and the developments that led up to their design, and should be of value to those interested in the development of the slide rule. The book also contains a list of the rules designed and used since 1800. There are 74 pages of reading matter, which is well illustrated and indexed. Price $1.00.

CIVIL ENGINEERING CLUB.

The C. E. Club began the first semester of 1909-10 with E. S. Pennebaker, Pres., C. A. Nye, Vice Pres., W. A. North, Sec., S. Standish, Treas., and M. S. McCollister, Sergeant-at-arms. The following chairmen of the different committees were appointed by the president: S. Standish, program, K. L. Ponzer, membership, M. B. Stewart, advertising.

The first semester was very successful in the matter of lectures. Some of the most successful Engineers of this country spoke to good audiences. Among these speakers were the following men:

Dean F. E. Turneaure, Univ. of Wisconsin.

W. H. Zimmerman, of Chicago.
T. L. Condron, of Chicago.
A. S. Baldwin, Chief Eng. of the I. C. R. R.
Onward Bates, Pres. of A. S. of C. E.
Dean Ricker, Univ. of Illinois.
E. Keough, '07, Roadmaster on C. B. & Q.
G. E. Tibbetts, '99, Bridge Eng., C. B. & Q.

Honorary membership was voted to the speakers after the talks. The membership committee did good work and secured 120 members. This gave the club the largest membership of the Engineering Societies at Illinois.

The officers elected for the second semester were as follows:

Pres. S. Standish, Vice Pres., H. C. Boardman, Sec. E. Juergens.

The annual Smoker is still being talked about. The committee with K. L. Ponzer, '10, as chairman, has been appointed and plans are under way.

One feature of the C. E. Club this year has been the talks given by the members themselves. Their talks were on experiences that they had while on work of different kinds. Among those that talked were the following seniors:—G. H. Smith, K. L. Ponzer, W. E. Deuchler, F. W. Weston, I. G. Ferguson, and G. W. Rathjens.

ARCHITECTURAL CLUB.

During the past year the Architectural Club has been particularly active. For the first time in several years a systematic course of lectures was arranged and carried out. The first semester a series of eight lectures was given by professors of the Architectural and Art and Design Departments and the course was continued during the second semester by practicing architects from Chicago and other cities.

The annual convention of the Architectural League of America, of which organization this Club is a member, was held in Washington, D. C., from December eleventh to fourteenth. The Club's interests were ably represented in the person of Mr. Leon F. Urbain, who was elected secretary of the

convention. The Architectural Club is one of the few student organizations that are members of the League and in having their delegate elected to such an inpomtant office they received no small honors.

The progressiveness of this year's club was well demonstrated when an official club pin was adopted. Efforts had been made in previous years to select a pin but to no avail. This year a competition was held for pin designs and was won by a senior, Mr. Robert T. Jones.

A year book of work done exclusively by the Club was started during the second semester and at the time of writing was well under way.

The Club was one of the four promoters of the first Engineering Dance, which was a great success.

The officers for the first semester were; L. F. Urbain, President; R. T. Jones, Vice President; S. F. Cannon, Treasurer; C. H. Schnetzler, Secretary. For the second semester: S. F. Cannon, President; F. A. Ward, Vice President; F. B. Gray, Treasurer; W. J. Klein, Secretary.

THE STUDENT BRANCH OF THE A. S. M. E.

At the close of last year a new society was formed at the University, as a section of the American Society of Mechanical Engineers. The object of this organization is to read and discuss papers presented before the main body, as they are published in "The Journal," the official organ of the society.

During the year just closed nearly all of the members in school gave a resume and discussion of some article. These have proven especially interesting and an immense amount of good has been derived from them.

The officers are elected annually in February and are all chosen from the Junior class. For the first year they were as follows: Pres., W. F. Coleman; Vice-president, F. E. Sperry; Secretary, S. G. Wood; Treasurer, D. Rugg. For the new term the officers are President, B. L. Keown; Vice President, B. Bannister; Secretary, E. S. Huntington; Treasurer, H. C. Heilman. Juniors and Seniors in Mechanical Engineering are eligible to membership.

MECHANICAL ENGINEERING SOCIETY. 132

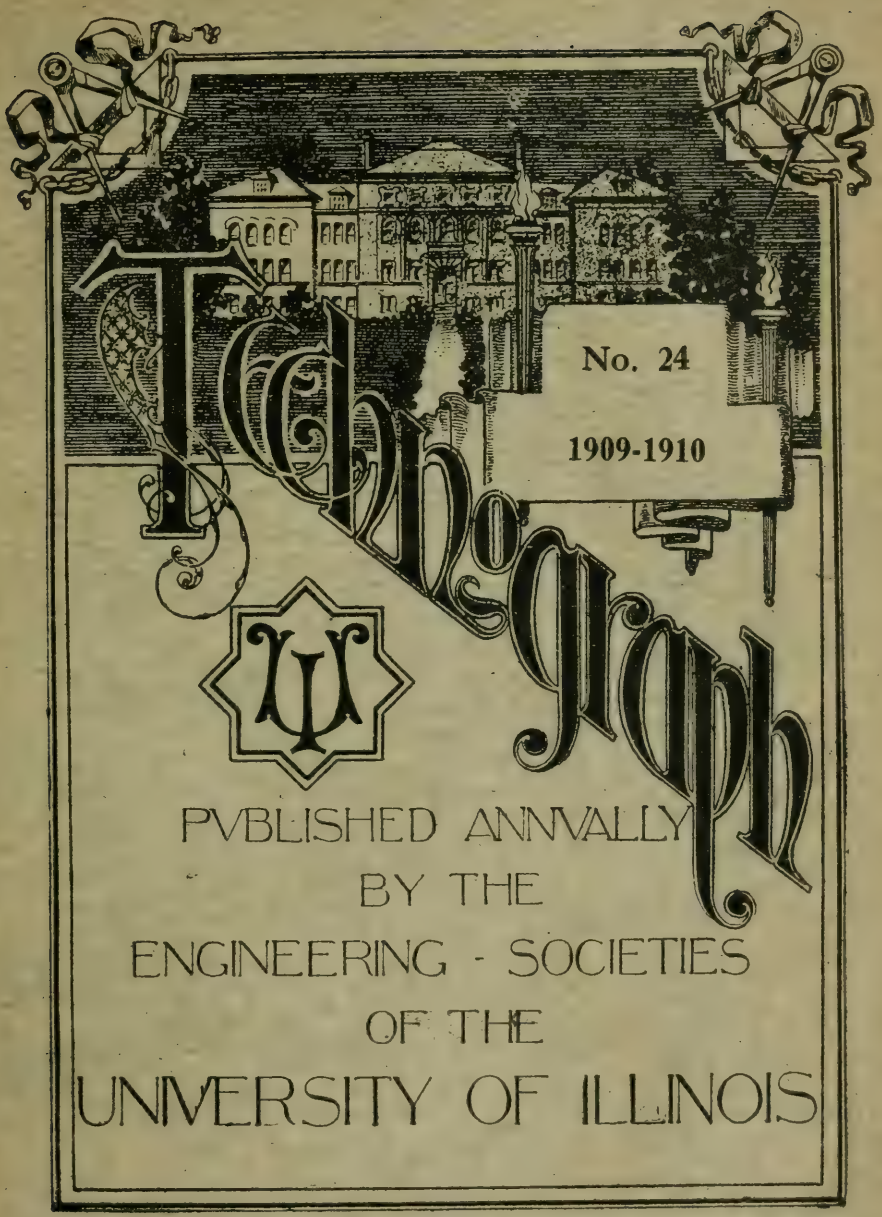
The officers of the M. E. Society for 1909-10 were D. C. Patton, '10, Pres., J. C. Parmely '10, Vice Pres., J. C. Mackey '10, Secy and I. B. Altekruse '10, Treas. For 1910-11 the officers are D. W. Kreidler, '11, Pres., W. C. Anthony, '11, Vice Pres., S. A. Schickedanz, Secy and H. C. Krannert, Treas. According to the revision of the constitution, the president and treasurer hold office for one year beginning with the second semester.

The society has been unusually successful this year due for the most part to student programs. Some of these were, "Gas Producers and Engines" by J. C. Parmely '10 and F. E. Sperry '10. "The Construction and Testing of Automobiles" by D. W. Kreidler, '11, A. O. Spierling, '10 and W. C. Anthony, '11 and "A Wire Guage Table from the Slide Rule" by O. A. Carnahan, '10.

Outside speakers were Mr. William Kent, M. Am. Soc. M. E. on "The Engineer." Mr. M. B. Stewart of the department of agriculture on "The Illinois Tunnel System" and Mr. E. T. Clarage, Pres. of the Columbia Steel Co. on "Tool Steels and Their Use."

In the early part of the year a smoker was held in Hessel hall in Champaign at which there was an attendance of over one hundred and fifty. Besides the smoker and eats there was an excellent program given by members of the faculty and senior students. This affair gave an impetus to the society at the start of the year and was so successful that a like event will be given about May as a final round-up before the close of the school year.

1. 24



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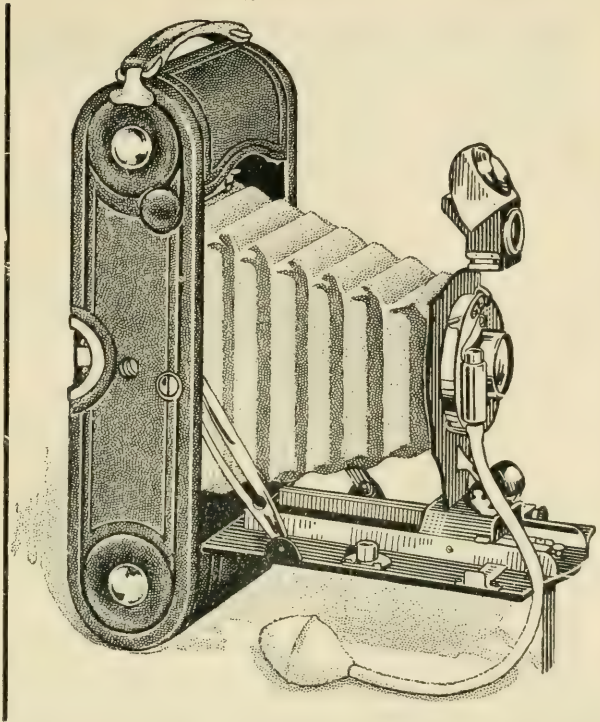

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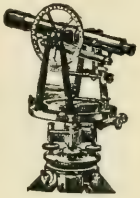

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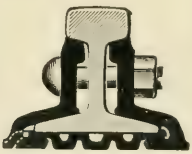

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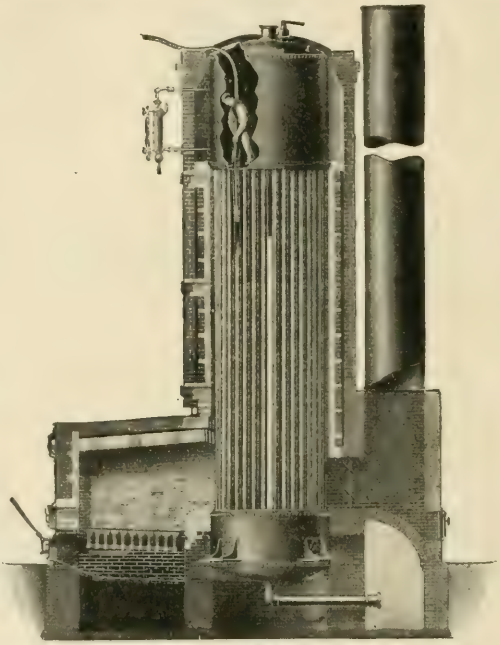

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